The Relationship between the Project Size and the Safety Level in Building Construction Projects

by

Misfer A. Al-Utaibi

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

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This thesis, written by AL-UTAIBI, MISFER under the direction of his Thesis Advisor and approved by his Thesis Committee, has been presented to and accepted by the Dean of College of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING & MANAGEMENT.**

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This thesis is dedicated to my parents, my wife and my sons Aied, Faris and Naif.

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THESIS ABSTRACT

NAME : Misfer Al-Otaibi

Title : The Relationship Between Project Size and Safety Levels on Building Construction Projects.

Major : Construction Engineering And Management

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This thesis evaluates the safety levels found on building construction projects in the Eastern Province of Saudi Arabia. A total of forty-five projects were surveyed in this research. Ten of these projects were classified as large projects, each with a monetary value greater than twenty million Saudi Riyals. Fifteen were classified as medium projects, each with a monetary value ranging from five million to twenty million Saudi Riyals. The other twenty were small projects, each with a monetary value of less than five million Saudi Riyals.

The survey comprises two parts. The first part is in the form of an Inspection Checklist which contains eighteen divisions, each division containing a certain numbers of items. The safety level on each project is compared with that project's accident rate. The second part consists of a questionnaire which was designed to identify middle management practices on safety for each project.

MASTER OF SCIENCE DEGREE

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
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خلاصة الرسالة

الأســـم : **مسفر عايد مسفر العتيبي**

العنـــوان : **العلاقة بين حجم المشروع ومستوى السلامة في المباني العمرانية**

التخصص : **هندسة وإدارة التشييد**

يستعرض هذا البحث موضوع السلامة في المباني العمرانية بالمنطقة الشرقية من المملكة العربية السعودية . وقد تم تقييم أساليب السلامة على ٤٥ مشروعاً . عشرة (١٠) من هذه المشاريع كانت مشاريع كبيرة تبلغ تكلفة المشروع أكثر من عشرين مليون ريال سعودي . وخمسة عشرة (١٥) من هذه المشاريع كانت مشاريع متوسطة تبلغ تكلفة المشروع من هذه الفئة أكثر من خمسة (٥) مليون ريال سعودي وأقل من عشرين مليون ريال سعودي . والعشرين (٢٠) المتبقية كانت مشاريع صغيرة تكلفة المشروع أقل من خمسة مليون ريال سعودي .

تكون البحث من جزئين . الجزء الأول عبارة عن دراسة ميدانية تمثلت في تشكيل قائمة تحتوي على أهم العناصر الضرورية للسلامة والمفترض تواجدها في هذه المشاريع كما تم تحديد العلاقة بين مستوى السلامة ومعدل الحوادث في كل مشروع .

وفي الجزء الثاني قام الباحث بتوزيع ٢٢ سؤالاً وتم الرد على هذه الأسئلة من قبل مدير المشروع ومن خلال الإجابة على هذه الأسئلة تم تحديد نوعية مساهمة هذا المستوى الإداري في أساليب السلامة .

درجة الماجستير في العلوم

جامعة الملك فهد للبترول والمعادن

الظهران – المملكة العربية السعودية

١٤١٧/٠٢/٠٧هـ

CHAPTER 1

INTRODUCTION

In general accidents occur as a result of either unsafe acts or unsafe conditions. About 12 - 20 percent of accidents are attributed to unsafe conditions, while 70 - 86 percent are due to unsafe acts (Vincent, 1975). The increasing rate in both types of accidents caused the United State to pass a law, the Occupational Safety and Health Act (OSHA), in 1970.

OSHA mainly provides assurances to workers that each employer is obligated to provide a safe and healthy place of work. It focuses primarily on the physical conditions that exist in the work place and it specifies certain equipment to be used in certain tasks and proper protective equipment to be worn while performing specific tasks.

The Act puts the construction industry under scrutiny, since the industry is very well-known for its high accident rate when compared with other industries. Construction sites are sometimes unique and very complex, and they are considered among the most hazardous types of working environment.

The harsh environment on the construction sites sometimes leads to accidents that have unmeasurable consequences. Many companies declare their bankruptcy because they are not able to sustain the financial losses caused by accidents. Moreover, companies that are able to absorb the immediate cost of these accidents have a difficult time in the ensuing years . These companies are not able to compete in the market due to the fact that their images are badly damaged.

Another side-effect of accidents is humanitarian. The victim may receive a permanent injury or lose his life and such mishaps will negatively affect the productivity of his co-workers. The employees will have low morale and they will waste time discussing past accidents. This, of course, will add unnecessary costs to any company project.

Therefore projects which have a very effective safety program reduce their costs substantially. The most apparent reduction is in the cost of liability insurance premiums . Another type of cost will be the <u>hidden</u> costs, which are usually associated with accidents or injuries, such as:

- cost of overtime necessitated by the accident
- loss of efficiency of crew
- extra wages cost for long-term absentees
- clean-up, repairs, replacement and stand-by costs
- cost of orientation/training the replacement workers
- cost of rescheduling the work
- safety/clerical personnel costs of the accident.

Safe contractors will be able not only to reduce costs and compete with others, but they will have very important benefits from an excellent safety system. Perhaps the most important one is humanitarian, which is saving other people's lives and preventing personal injuries and deaths within the organization or the company. Another benefit will be to boost the morale of their supervisors and workers. In addition, the company's image and its relations with the public will improve.

Therefore, safety is a very important element in the success of any construction project. It has a major impact on the contractor, owner, workers, and on the environment. In many countries a contractor safety sheet or performance record is considered one of the items that qualifies a contractor for a bid. Furthermore, many public agencies include safety standards as part of the construction contract documents, which then become a contractual obligation as well as a legal one.

With the importance of safety in mind, the thesis investigates and assesses the safety level among different construction projects in the Eastern Province of Saudi Arabia. A total of forty-five projects are surveyed. They are classified as large, medium, and small. The projects are classified according to the monetary value of each project. If the project costs are over twenty million Saudi Riyals, it is classified as a large project. Medium project costs are between five million and twenty million, while small project costs are less than five million Saudi Riyals. The representative sample of each group is ten, fifteen and twenty projects respectively.

The two major contributors to accidents, that is, unsafe conditions and unsafe acts, will be investigated and measured in the project. The unsafe conditions will be measured through a developed inspection checklist. Appendix I consists of 18 divisions , each division having a certain number of items. Furthermore, a questionnaire in Appendix II consists of twenty-two questions which were utilized to measure and evaluate middle management involvement in minimizing or eliminating unsafe acts.

Each project safety level that has been determined from the Inspection Checklist, is linked to the project's accident records, to project size and to the middle management practices on safety.

1.2 SIGNIFICANCE OF THE STUDY

Construction is the second most prominent activity in the Kingdom of Saudi Arabia, as 25.4% of all establishments are engaged in this activity. More specifically, 29% of all establishments operating within the Eastern Province are engaged in construction, according to the General Organization for Social Insurance in Saudi Arabia (Sixteenth Annual Statistical Report, 1995).

Construction is the prominent activity as to the number of registered workers (1,896,590). It absorbs 50% of all registered workers. This is quite normal, because the Kingdom is witnessing a phase of building and development in various aspects. Government projects are being completed for various purposes. Furthermore, buildings for individual use as well as for investment purposes are being constructed by finance from the Real Estate Development Fund.

The total benefit payments made under the occupational hazards' scheme (OHS) during the financial year 1994 amount to approximately 146 million Saudi Riyals.(General Organization for Social Insurance in Saudi Arabia, Sixteenth Annual Statistical Report, 1995).

The statistics show that this number is on the rise and will increase in the coming few years. One of the major contributions to this increase is the weak control and lack of inspection of the safety measures establishments are supposed to employ.

Accidents in the construction industry result in many injuries and deaths and huge amounts of money are lost because of these accidents. Therefore, this thesis will investigate the safety aspects of building construction projects in the Eastern Province of Saudi Arabia and compare the safety performance found on large, medium, and small projects.

1.3 BENEFITS OF THE STUDY

In general, projects which have a very effective safety program reduce their costs substantially. The ostensible reduced costs will be the Workmen's Compensation Costs and Liability Insurance Premiums' Cost. The other types of cost will be the hidden ones, which are usually associated with accidents or injuries.

The study will have a great benefit and impact on the construction industry in Saudi Arabia. It will clearly show how safety is valued and perceived among Saudi Contractors, and it will pin-point the areas of deficiencies.

In addition, the study will establish the relations between the safety program and the size of the project and identify the strengths and weaknesses of the current safety and health program in those companies.

1.4 OBJECTIVES

The main objectives of the research are as follows:

1. To assess the site safety level in the Construction Industry in the Eastern Province of Saudi Arabia.

2. To measure the correlation between the site safety level and the accident rate.

3. To identify the effect of middle management practices on safety.

1.5 SCOPE & LIMITATIONS

The following is considered as the limitations of the study:

- the survey will cover only on-going construction projects in the Eastern Province of Saudi Arabia.

- the survey is limited to building construction projects.

1.6 THESIS ORGANIZATION

This report consists of six chapters. The first chapter emphasizes the significance of the study and its objectives. The second chapter presents previous efforts and studies which have been made in the field of safety. Chapter three presents a background and detailed criteria and requirements for the elements that have been utilized in the inspection checklist, to evaluate the safety level in each project. Chapter four deals with the methodology of this report. The fifth chapter presents the calculation and data analysis, while the sixth chapter presents the conclusions of the research.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Safety has become an integral part of any organization or company not only in the construction industry but in other industries as well. However, construction workers are in a high-risk industry, along with those in agriculture and mining / quarrying. This statement reflects a reality that has been established in the past safety performances in the industry. Work deaths and death rates among different industries were presented in Accident Fact 1993 and are shown in Table # 1.

Table 1. Work Deaths and Death Rates by Industry Division, 1984-1992

Year	Agri-culture	Mining & Quarrying	Con-struction	Manu-facturing	Trans. & Pub. Util.	Trade	Services	Govern-ment
				DEATHS				
1984	1700	500	2200	1100	1600	1200	1800	1400
1985	1600	400	2400	1200	1500	1300	1800	1300
1986	1800	300	2300	1000	1600	1100	1600	1400
1987	1700	300	2100	1000	1500	1200	2000	1500
1988	1500	300	2200	1000	1500	1200	1600	1600
1989	1300	300	2100	1000	1500	1200	1700	1700
1990	1300	300	2100	1000	1200	1100	1400	1700
1991	1400	300	1800	800	1100	900	1500	1500
1992	1200	200	1300	600	1200	1000	1300	1700
				DEATH RATES*				
1984	49	50	39	6	29	5	7	9
1985	49	40	40	6	27	5	6	8
1986	55	38	37	5	29	4	5	8
1987	53	38	33	5	26	5	6	9
1988	48	38	34	6	26	4	5	9
1989	42	43	32	6	25	4	5	10
1990	42	43	33	5	20	4	4	10
1991	44	43	31	4	18	3	4	8
1992	37	29	22	3	20	4	3	9

** DEATHS PER 100,000 WORKERS IN EACH INDUSTRY GROUP.*

Due to the high frequency rate of injuries and fatalities in the construction industry, more attention has been given to safety systems. The true costs of injuries and accidents are far more than the insurable or direct costs. For these reasons, recent years have been marked by an increasing awareness in the construction industry about safety and its importance.

Many high-ranking officials in the construction companies or organizations regard safety as being as important to their survival as production, quality and workers' morale. Several methods of measuring the safety performance have been devised and used by industrial government agencies and safety organizations. However, there is no standardized measure existing.

It would be ideal to have some kind of yardstick that would enable us to measure safety performance in much the same way that we can measure height, weight, reaction time and intelligence. Many of the safety measures that have been used by safety professionals have certain limitations, when attempts are made to convert audit results into weighted values. However, if the literature is evaluated, it appears that there are five common ways of measuring:

- Audits
- Profiles
- Management Oversight and Risk Tree (MORT)
- Surveys
- Checklists.

2.2 AUDITS:

The safety audit is a management tool that can be used to measure the effectiveness of an organization's safety program in meeting its goal and objectives. A properly conducted safety audit should be performed by selected people who are not involved in the operation and it should accomplish the following:

- determine if the organization's safety program is meeting its objectives or goals.
- establish employee participation and personal accountability in safety matters.
- evaluate the effectiveness of the safety program regardless of the strengths and the weakness of other areas within the organization
- identify and correct any operation, procedure or equipment that is in violation of laws, regulations and standards.
- identify the strengths and weakness of the current safety system
- constitute a basis in formulating an improvement plan that can easily be communicated to all levels of management within the organization.

Safety and health audits can be classified as follows:

- a comprehensive audit which is conducted for the purpose of reviewing all aspects of an organization's safety and health program. This is a rather time-consuming process, but, when conducted properly, it can identify all problem areas that might adversely affect the success of the safety and health program.

- a limited audit which focuses attention on a particular area or program.

- a formal audit which normally follows a detailed and structured evaluation system. This type of audit usually results in a very well documented report addressing specific safety problems within the organization.

- an informal audit which is conducted for the purpose of identifying specific safety problems and usually results in interim status safety reports.(Peterson, 1989).

The mechanics to perform audits are very simple and the format consists of three parts:

1- ACTIVITY STANDARDS

Each organization is rated in different areas and each area consists of key activities. Each activity is clearly defined and has a four rating, viz Poor, Fair, Good, Excellent. The requirement for each rating is defined in Table 2.1.

Table # 2.1 Activity Standards Measurement Technique (Peterson, 1989)

ACTIVITY STANDARDS					
A. ORGANIZATION & ADMINISTRATION					
	Activity	**Poor**	**Fair**	**Good**	**Excellent**
1	Statement of policy, responsibilities assigned.	No statement of Loss Control policy. Responsibility and accountability not assigned.	A general understanding of Loss Control, responsibility and accountability, but not written.	Loss Control Policy and responsibilities written and distributed to supervisors.	In addition to "Good" Loss Control Policy is reviewed annually and is posted. Responsibility is emphasized in supervisory performance evaluations.
2	Safe operating procedures (SOP's).	No written SOP's	Written SOP's for some, but not all hazardous operations	Written SOP's for all hazardous operations.	All hazardous operations covered by a procedure, posted at the job location, with an annual documented review to determine adequacy.
3	Employee selection and placement.	Only pre-employment physical examination given.	In addition, an aptitude test is administered to new employees.	In addition to "Fair" new employees' past safety record is considered in their employment.	In addition to "Good": when employees are considered for promotion, their safety attitude and record is considered.
4	Emergency and disaster control plans.	No plan or procedures.	Verbal understanding on emergency procedures.	Written plan outlining the minimum requirements.	All types of emergencies covered with written procedures. Responsibilities are defined with back up personnel provisions.
5	Direct management involvement.	No measurable activity.	Follow-up on accident problems.	In addition to "Fair" management reviews all injury and property damage reports and holds supervision accountable for verifying firm corrective measures.	In addition to "Good" reviews all investigation reports. Loss Control problems are treated as other operational problems in staff meeting.
6	Plant safety rules.	No written rules.	Plant safety rules have been developed and posted.	Plant safety rules are incorporated in the plant work rules.	In addition, plant work rules are firmly enforced and updated at least annually.

ACTIVITY STANDARDS					
B. INDUSTRIAL HAZARD CONTROL	**Activity**	**Poor**	**Fair**	**Good**	**Excellent**
1	House-keeping & storage of materials, etc.	Housekeeping is generally poor. Raw material items being processed and finished materials are poorly stored.	Housekeeping is fair. Some attempts to adequately store materials are being made.	Housekeeping and storage of materials are orderly. Heavy and bulky objects well stored out of aisles, etc.	Housekeeping and storage of materials are ideally controlled.
2	Machine-guarding.	Little attempt is made to control hazardous points of machinery.	Partial, but inadequate or ineffective, attempts at control are in evidence.	There is evidence of control which meets applicable Federal and State requirements but improvement may still be made.	Machine hazards are effectively controlled to the extent that injury is unlikely. Safety of operator is given prime consideration at time of process design.
3	General area guarding.	Little attempt is made to control such hazards as unprotected floor openings, slippery or defective floors, stairway surfaces, inadequate illuminations, etc.	Partial, but inadequate or ineffective maintenance.	There is evidence of control which meets applicable Federal and State requirements - but further improvement may still be made.	These hazards are effectively controlled to the extent that injury is unlikely.
4	Maintenance of equipment, guards, hand-tools, etc.	No systematic program of maintaining guards, handtools, controls and other safety features of equipment, etc.	Partial, but inadequate or effective maint-enance.	Maintenance program for equipment and safety features are adequate. Electrical hand-tools are tested and inspected before issuance, and on a routine basis.	In addition to "Good" a preventive maintenance system is programmed for hazardous equipment and devices. Safety report files and safety department consulted when abnormal conditions are found.
5	Material handling hand and mechanized.	Little attempt is made to minimize possibility of injury from the handling of materials.	Partial but inadequate or ineffective attempts at control are in evidence.	Loads are limited as to size and shape for handling by hand, and mechanization is provided for heavy or bulky loads.	In addition to controls for both hand and mechanized handling. Adequate measures prevail to prevent conflict between other workers and material being moved.
6	Personal protective equipment, adequacy and use.	Proper equipment not provided or is not adequate for specific hazards.	Partial but inadequate or ineffective provision, distribution and use of personal protective equipment.	Proper equipment is provided. Equipment identified for special hazards, distribution of equipment is controlled by supervisors. Employee is required to use protective equipment.	Equipment provided complies with standards. Close control maintained by supervision. Use of safety equipment recognized as an employment requirement. Injury record bears this out.

ACTIVITY STANDARDS					
C. FIRE CONTROL AND INDUSTRIAL HYGIENE					
	Activity	**Poor**	**Fair**	**Good**	**Excellent**
1	Chemical hazard control references.	No knowledge or use of reference data.	Data available and used by Foreman when needed.	In addition to "Fair" additional standards have been requested when necessary.	Data posted and followed where needed. Additional standards have been promulgated, reviewed with employees involved and posted.
2	Flammable and explosive materials control.	Storage facilities do not meet fire regulations. Containers do not carry name of contents. Approved dispensing equipment not used. Excessive quantities permitted in manufacturing areas.	Some storage facilities meet minimum fire regulations. Most containers carry name of contents. Some approved dispensing equipment in use.	Storage facilities meet minimum fire regulations. Most containers carry name of contents. Approved equipment generally is used. Supply at work areas is limited to one day requirements, containers are kept in approved storage cabinets.	In addition to "Good" storage facilities exceed the minimum fire regulations and containers are always labeled. A storage policy is in evidence relative to the control of the handling, storage and use of flammable materials.
3	Ventilation fumes, smoke and dust control.	Ventilation rates are below industrial hygiene standards in areas where there is an industrial hygiene exposure.	Ventilation rates in exposures areas meet minimum standards.	In addition to "Fair" ventilation rates are periodically measured, recorded and maintained at approved levels.	In addition to "Good" equipment is properly selected and maintained close to maximum efficiency.
4	Skin contamination control.	Little attempt at control or elimination of skin irritation exposures.	Partial, but incomplete program for protecting workers. First aid reports on skin problems are followed up on an individual basis for determination of cause.	The majority of workmen in structured concerning skin-irritating materials. Workmen provided with approved personal protective equipment or devices .	All workmen informed about skin-irritating materials. Workmen in all cases provided with approved personal protective equipment or devices.
5	Fire control measured.	Do not meet minimum insurance or municipal requirements.	Meets minimum requirements.	In addition to "Fair" additional fire hoses and/or extinguishers are provided. Welding permits issued. Extinguishers on all welding carts.	In addition to "Good" a fire crew trained in emergency procedures and in the use of the fighting equipment..

ACTIVITY STANDARDS					
C. FIRE CONTROL AND INDUSTRIAL HYGIENE					
	Activity	**Poor**	**Fair**	**Good**	**Excellent**
6	Waste-trash collection and disposal, air/water pollution.	Control measures are inadequate.	Some controls exist for disposal of harmful wastes or trash. Controls exist but are ineffective in methods or procedures of collection and disposal. Further study is necessary.	Most waste disposal problems have been identified and control programs instituted. There is room for further improvement.	Waste disposal hazards are effectively controlled. Air/water pollution is minimal..
D. SUPERVISORY PARTICIPATION, MOTIVATION AND TRAINING					
1	Line supervisor safety training	All supervisors have not received basic safety training.	All shop supervisors have received safety training.	All supervisors participate in division safety training session, a minimum of twice a year	In addition, specialized sessions conducted problems.
2	Indoctrination of new employees.	No program covering the health and safety requirements	Verbal only	A written handout to assist in indoctrination.	Formal indoctrination program to orientates new employees is in effect.
3	Job hazard analysis.	No written program.	Job hazard analysis program being implemented on some jobs.	JHA conducted on majority of operations.	In addition, job hazard analyses performed on a regular basis and safety procedures written and posted for all operations.
4	Training for specialized operations (Fork trucks, grinding, press brakes, punch presses, solvent handling etc.)	Inadequate training given for specialized operations	An occasional training program given for specialized operations.	Safety training is given for all specialized operations on a regular basis and retraining given periodically to review correct procedures.	In addition to "Good" an evaluation is performed to determine training needs.
5	Internal self-inspection.	No written program to identify and evaluate hazardous practices and/or conditions.	Plant relies on outside sources, i.e. insurance safety engineers and assumes each supervisor inspects his area.	A written program outlining inspection guideline responsibilities frequency and follow-up is in effect.	Inspection program is measured by results, i.e. reduction in accidents and costs. Inspection results are followed up by top management.

D. SUPERVISORY PARTICIPATION, MOTIVATION AND TRAINING					
	Activity	Poor	Fair	Good	Excellent
6	Safety promotion and publicity.	Bulletin-board posters are considered the primary means for safety promotion.	Additional safety displays, demonstrations, films are used infrequently	Safety displays, demonstrations, are used on regular basis	Special display cabinets, windows, etc, are provided. Displays are used regularly and are keyed to special themes.
E. ACCIDENT INVESTIGATION, STATISTICS AND REPORTING PROCEDURES					
1.	Accident investigation by line personnel.	No accident investigation made by line supervision.	Line supervision makes investigations of only medical injuries.	Line supervision makes complete and effective investigations of all accidents, the cause is determined, corrective measures initiated immediately with a completion date firmly established.	In addition to items covered under "Good" investigation is made of every accident within 24 hours of occurrence. Reports are reviewed by the department manager and plant manager.
2	Accident cause and injury location analysis and statistics.	No analysis of disabling and medical cases to identify prevalent causes of accidents and locations where they occur.	Effective analysis by both cause and location maintained on medical and first aid cases.	In addition to effective accident analysis, results are used to pinpoint accident causes so accident prevention objectives can be established.	Accident causes and injuries are graphically illustrated to develop the trends and evaluate performance. Management is kept informed on status.
3.	Investigation of property damage.	No program.	Verbal requirement or general practice to inquire about property damage accidents.	Written requirement that all property damage accidents of $50 and more will be investigated.	In addition, management requires a vigorous effort on all property damage accidents.
4.	Proper reporting of accidents and contact with carrier.	Accident reporting procedures are inadequate.	Accidents are correctly reported on a timely basis.	In addition to "Fair" accident records are maintained for analysis purposes.	In addition to "Good" there is a close liaison with the insurance carrier.

2-• RATING FORM

Each rating is assigned a value as illustrated below. Then each activity will be assigned values based on its rating. Then each rating value for all activities within an area is summed up. Then the details of all readings are added up and multiplied by the weight of the area to give the final rating of that specific area

. **RATING FORM**

A. ORGANIZATION & ADMINISTRATION

	Poor	Fair	Good	Excellent	Comments
1. Statement of policy, responsibilities assigned.	0	5	15	20	
2. Safe operating procedures (SOP's)	0	2	15	17	
3. Employee selection and placement	0	2	15	12	
4. Emergency and disaster control planning.	0	5	15	18	
5. Direct management involvement.	0	10	20	25	
6. Plant safety rules.	0	2	5	8	
Total value of circle numbers	____ +	____ +	____ +	____	x.20 Rating

B. INDUSTRIAL HAZARD CONTROL

	Poor	Fair	Good	Excellent	Comments
1. Housekeeping - storage of materials.	0	4	8	10	
2. Machine-guarding.	0	5	16	20	
3. General area guarding	0	5	16	20	
4. Maintenance of equipment. guards, hand tools, etc.	0	5	16	20	
5. Materials' handling - hand. and mechanized	0	3	8	10	
6. Personal protective equipment adequacy and use.	0	4	16	20	

Total value of circle numbers ___ + ___ + ___ + ___ x.20 Rating

C. FIRE CONTROL & INDUSTRIAL HYGIENE

		Poor	Fair	Good	Excellent	Comments
1.	Chemical hazards control references		0	6	17	20
2.	Flammable and explosive materials' control		0	2	15	17
3.	Ventilation - fumes, smoke and dust control		0	2	8	10
4.	Skin contamination control		0	3	10	15
5.	Fire control measure		0	2	8	10
6.	Waste - trash collection and disposal air/water pollution		0	7	20	25

___ ___ ___ ___ x .20 Rating ___

D. SUPERVISOR PARTICIPATION, MOTIVATION & TRAINING

1.	Line supervisor safety training	0	10	22	25
2.	Indoctrination of new employee	0	1	5	10
3.	Job hazard analysis	0	2	8	10
4.	Training for specialized operations	0	2	7	10
5.	Internal self-inspection	0	5	14	10
6.	Safety promotion and publicity	0	1	4	15
7.	Employee/supervisor contact and communication	0	5	20	25

___ + ___ + ___ + ___ x.20 Rating

E. ACCIDENT INVESTIGATION, STATISTICS AND REPORTING PROCEDURES

1.	Accident investigation by line supervisor	0	10	32	40
2.	Accident cause and injury location analysis and statistics	0	3	8	10
3.	Investigation of property damage	0	10	32	40
4.	Proper reporting of accident and contact with carrier	0	3	8	10

Total value of circled number ___ + ___ + ___ + ___ .20 Rating

SUMMARY SHEET

The final score for each area calculated in the rating form will be registered in the sheet below. Then the scores for all areas will be added to give the final rating of the organization.

The numerical values below are the weighted ratings calculated on rating sheets. The total becomes the overall score for the location.

SUMMARY

		RATING
A.	Organization & Administration	______
B.	Industrial & Hazard Control	______
C.	Fire Control & Industrial Hygiene	______
D.	Supervisory Participation, Motivation & Training	______
E.	Accident Investigation Statistics & Reporting Procedures	______
	TOTAL RATING	______

2.2.1 *Qualification of an Auditor*

In order to conduct an effective safety audit, the auditor must have the following qualifications:

- Enough education and training in the areas of audits.
- Previous work experience in the area
- Adequate investigative and analytical skills
- Objectivity and independence
- Adequate communication skills.

2.3 PROFILING:

Profiling consists of the development of a standard of corporate safety performance in a number of categories considered to be important. Then companies are compared to the standard and a profile is made to show how the company compares to the standard in a number of categories. It is similar to auditing, but it is more elaborate and often accompanied by charts.

This safety measure approach was presented by Jack Fletcher, a Canadian safety professional, in his book *"The Industrial Environment"*. He rated and graded organizations and companies in the area of injury prevention, damage control, total loss control, guarding, inspection, design, committees and rules, training, investigation, record and analysis, and personal protective equipment. Furthermore, he provided a system of ratings from 0 to 5, or from unsatisfactory to excellent levels, and gave the criteria for each rating.

Another similar approach is offered by James Tye, Director General of the British Safety Council, in his book *"Management Introduction to Total Loss Control"*, where he rates an Organization in 30 different areas and each of the areas is then broken down into key elements. The safety performance is then rated on a percentage scale, as the table on pages 22 and 23 indicates.

Profiling is also used widely in the Union of South Africa. The National Occupational Safety Association (NOSA) uses a profiling approach to grade every industry.

Table 2.3 James Tye Master Evaluation and Development Grid

#	Item Description	0 %	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %	100 %
1	Management Involvement (Policy)											
2	Total Loss Control Manager (Professional Competence)											
3	Total Loss Control (Manager Technical Experience)											
4	Total Loss Control (Manager Aptitude and Talents)											
5	Accident Investigations (in depth)											
6	Plants and Facility Inspection.											
7	Laws, Policies Standards.											
8	Group Meetings (Management).											
9	Safety Committee Meetings.											
10	General Promotion (Posters, banners signs.)											
11	Personal Protection.											
12	Supervisory Training.											
13	Employee Training.											
14	Selection and Employment Procedures.											
15	Management Involvement (Policy)											

Continued

Key areas which call for priority action

Key areas which call for planning

Key areas were further action is not urgent

Table 2.3 Contd.

#	Item Description	0 %	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %	100 %
16	Occupational Health and Hygiene.											
17	Fire Prevention and Loss Control.											
18	Total Accident Control Accident Analysis.											
19	Personal Communications.											
20	Total Job Safety Analysis.											
21	Total Job Observations.											
22	Records and Statistics (National and Local Laws).											
23	Emergency Care (First Aid).											
24	Product or Service Liability.											
25	Off-the-Job Safety (Road and Home).											
26	Accident Recall and Analysis.											
27	Transport (including sales and management transport).											
28	Security (Program).											
29	Economic Applications.											
30	Pollution and Disaster Control.											

The area of management involvement is broken down into key elements and has an evaluation and development grid as shown in Table 2.4

Table 2.4: Evaluation and Development Grid: Key Area Management Involvement

Item Description	Need Priority Action			Area Needs Planning					Further Action Not Urgent		
	0 %	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %	100 %
• Is written safety policy issued ?											
• Is safety policy circulated to top, middle and supervisory management, to shop floor, apprentices and new entrants?											
• Is policy reissued quarterly in some written form?											
• Are executive safety inspections on quarterly basis?											
• Is safety policy enforcement effective?											
• Attitude of key management personnel to safety policy.											
• Is management action safety program operating effectively ?											
• Is an effective safety performance report made of management meetings?											
• Does supervisors' job appraisal include safety performance?											

Key areas which call for priority action

Key areas which call for planning

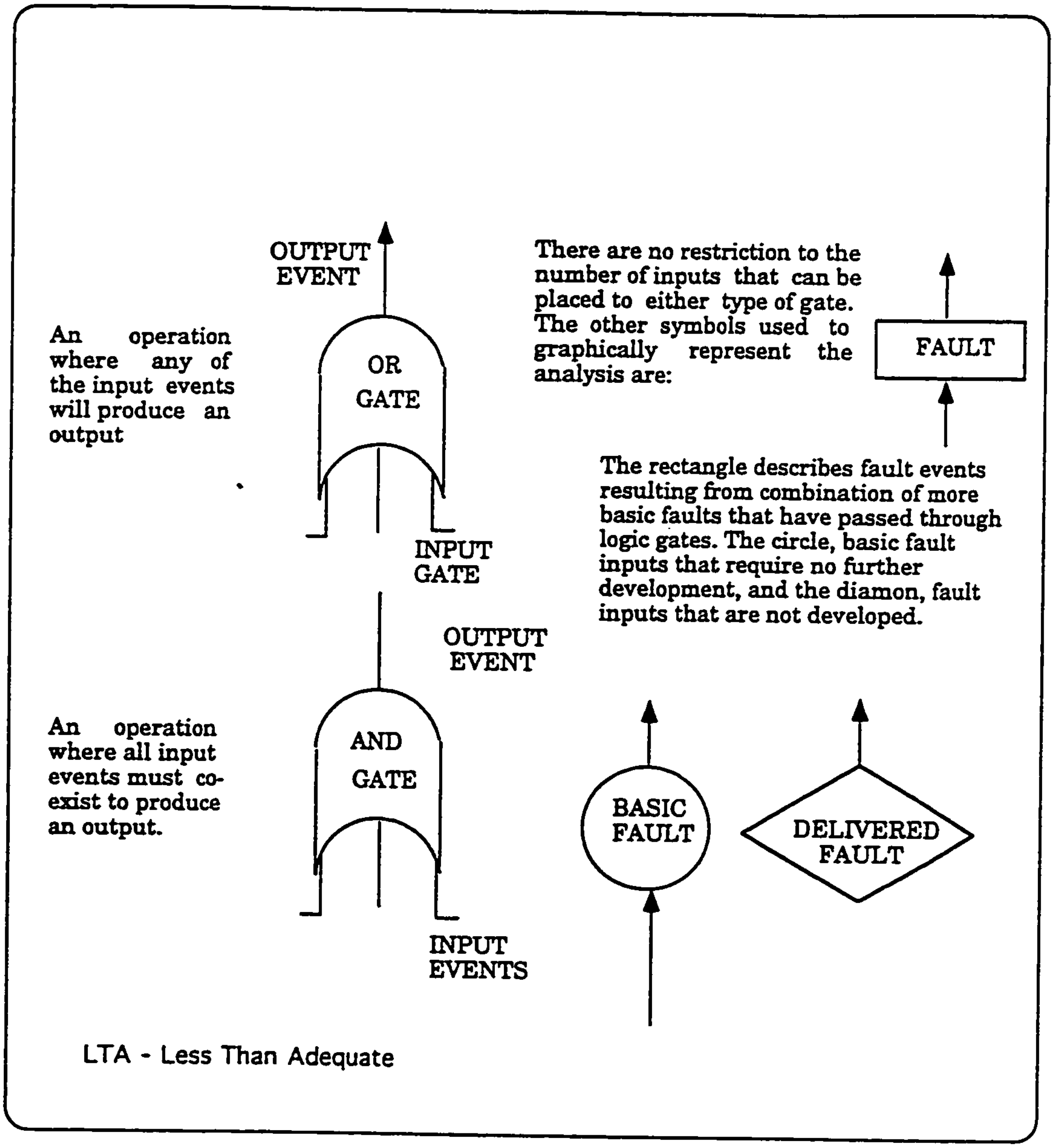
Key areas were further action is not urgent

2.4 MANAGEMENT OVERSIGHT AND RISK TREE (MORT)

Fault tree analysis has had a considerable application on construction projects. It was developed by scientists at Bell Laboratories to enable the identification of failure characteristics in a system. It is particularly useful for calculating failure event probabilities from failure rates of components.

The fault tree analysis is unique in that it reasons backward from a predetermined undesirable event. The tree is developed from the top down but read from the bottom up. However, the selection of events to be analyzed will be conditioned by the analyst's knowledge and imagination.

Table 2.5: MORT Systems Safety code
(Peterson, 1989)



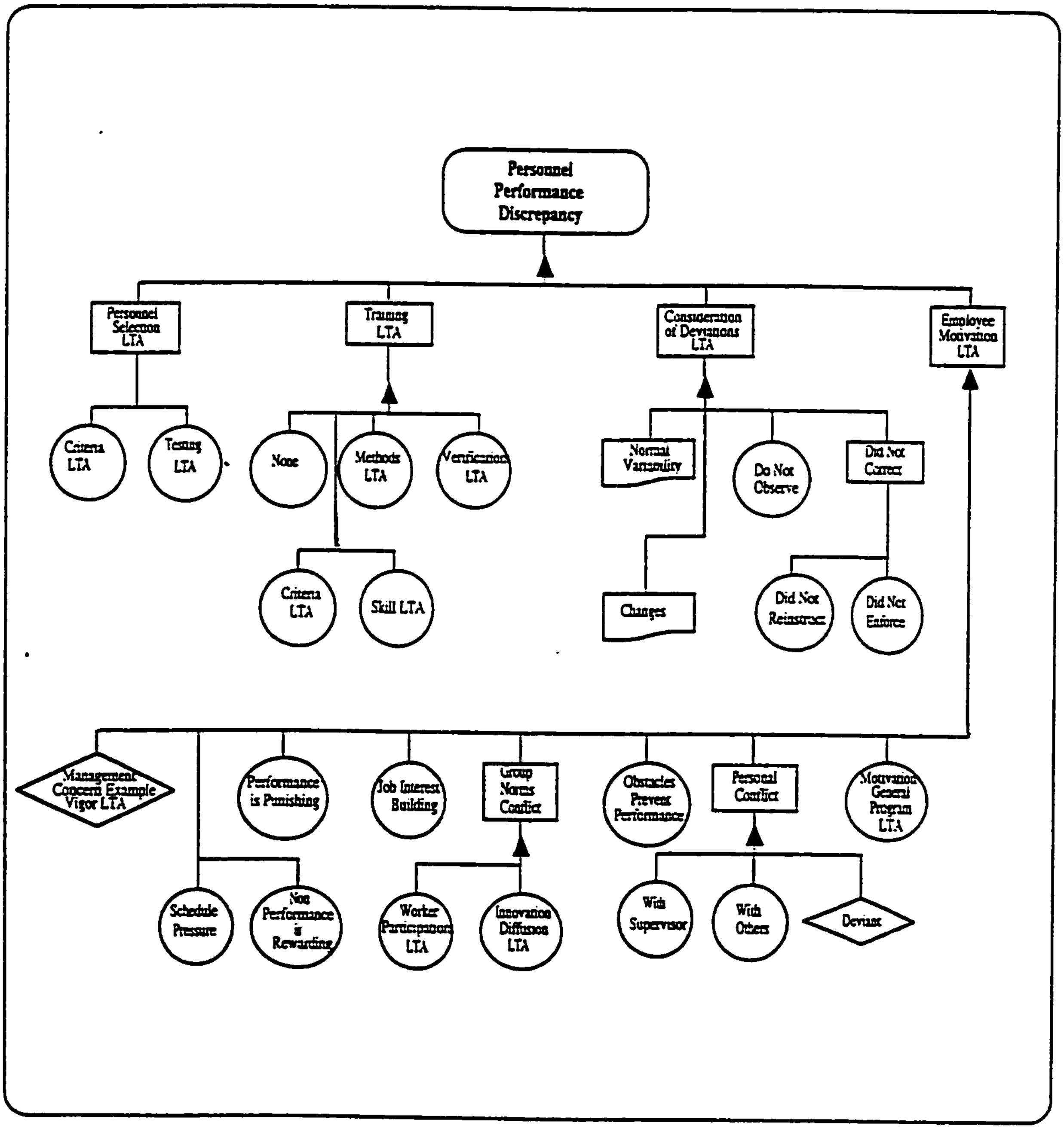


Table 2.6: MORT Human Error Fault Tree

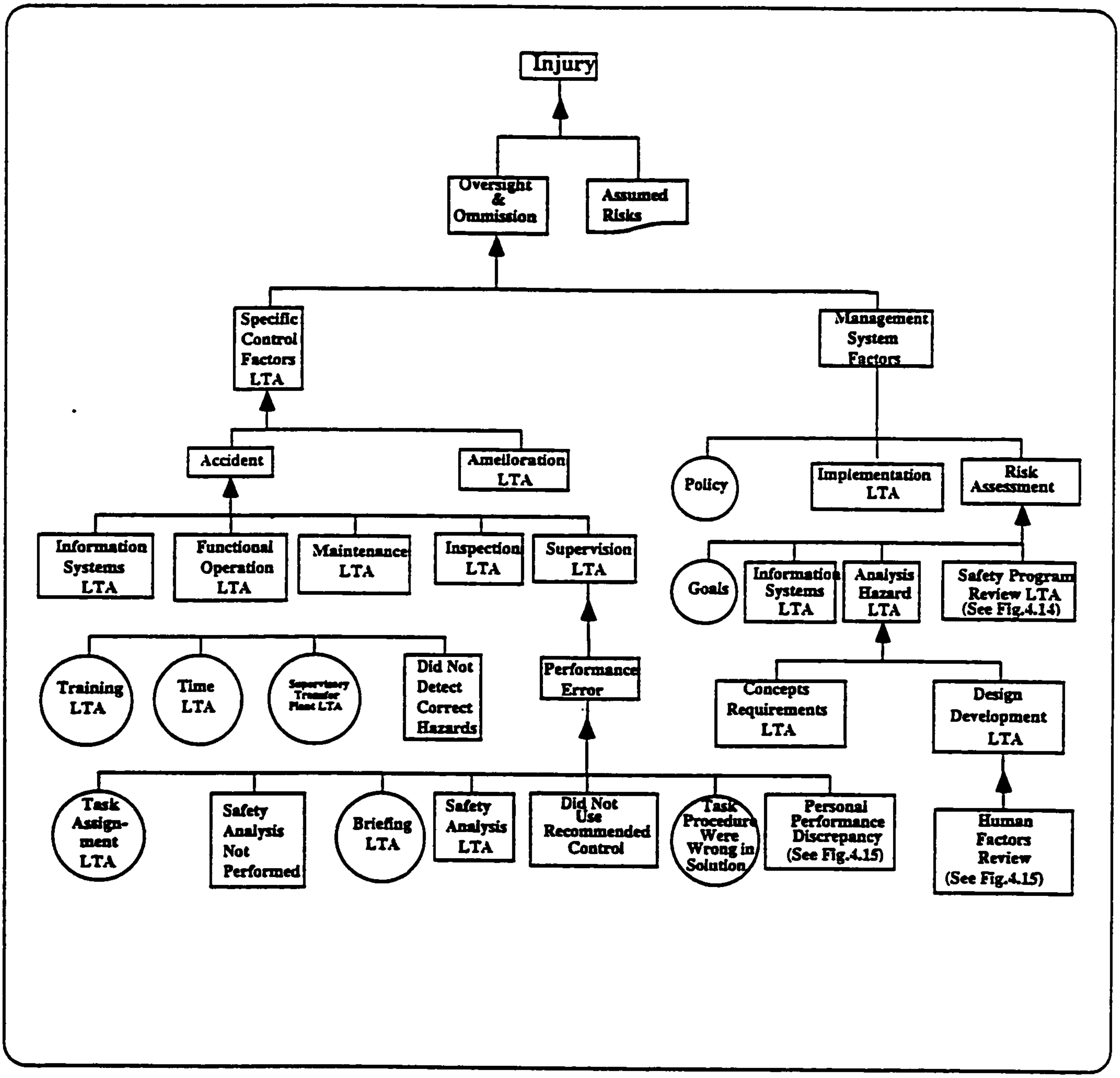


Table 2.7: Abbreviated MORT Fault Tree

2.5 SURVEYS

Another way of assessing the safety system is through the use of a survey. Hence the way the worker perceives the company safety program strongly influences his behavior and his ability to learn from and to respond to safety suggestions and materials. In a study by Social Research Inc., for Employers' Insurance of Warsaw (Peterson, 1989), they found that workers in different companies characterize their safety programs' consistency in any given company. As a result of this survey they classified companies into four types.

Over-zealous Company

This type of company puts a great deal of emphasis on safety. Safety equipment has to be worn and machines have to be guarded so as to make them difficult to get near or operate. This type of company imposes procedures. In such companies there seem to be endless safety meetings, safety films, safety manuals and safety procedures.

Rewarding Company

This type of company offers prizes for safety performance. The company distributes symbolic low-value prizes to its workers who did not commit safety violations. Even though the value of the prizes is relatively small, there is a sense of competition for them. The employees in such companies feel the importance of the safety programs and they feel that their superiors care about safety matters.

Lively Company

This type of company creates a safety program that stimulates competition among various departments within the company. Each department has to record the number of hours passed without accident and the winning department will receive a prize from the company. Safety in these companies becomes more than avoiding risks or accidents, it becomes a goal that needs to be achieved.

Negligent Company:

This type of company does not have an established safety program and it reacts to safety matters after the fact. These companies have no consideration for safety and they only look into it after a major accident happens. The workers feel that the company does not really care about safety and the distributed equipment and information material are only given out for the protection of the management.

2.5.1 Analyzing Climate

During the survey the safety program climate should be considered as well as the corporate climate in total. Both of these aspects of climate have a major influence on the behavior of both Manager and employees. One point of concern in the survey is that the employees' perception of the organization climate and philosophy may be different from that which is intended.

The difference in perception could be attributed to two possible reasons. The first factor could be lack of communication from the top to the bottom of the line in the organization. The second factor could be a discrepancy between the requirements and the actual occurrences. The closest point of contact between the management and the workers is the immediate supervisor. Therefore, if the supervisor's actions do not reflect the organizational philosophy, then a perception discrepancy occurs.

2.6 CHECKLIST

Checklist usage is very simple and effective in measuring safety systems. Its usage in analyzing safety systems goes back to the 1950s. Usually, the checklist consists of items whose presence or absence could jeopardize safe operation. These items are often checked by utilizing the Yes - No technique.

Most of the large industrial companies utilize the checklist technique, including Saudi Aramco.

This research used the checklist mechanism to determine the safety level in each project. The utilized checklist is similar to the one developed by Saudi Aramco. This consists of different areas and each area is broken down into different key elements. The areas that are of concern and presented in the checklist are:

- Site layout and housekeeping
- Protective equipment of Site Safety Administration
- Fire prevention
- Transportation
- Excavation and shoring

- Compressed gases
- Scaffolding
- Hand tools and power tools
- Concrete form work
- Cranes and lifting devices
- Air compressors
- Electrical connections
- Blasting
- Welfare facilities
- Heavy equipment
- Chemical handling.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

As is indicated in the Abstract, the survey of this thesis will cover large, medium and small projects. The project classification is based on its cost. The project that costs over twenty million is considered large. The project that costs between five and twenty million is considered medium, while the project that costs less than five million is classified as small.

The study was conducted in the field by surveying several construction projects in the Eastern Province of Saudi Arabia. The survey consists of two parts, a questionnaire and an inspection checklist.

3.2 INSPECTION CHECKLIST

The checklist is a modified version of the Saudi Aramco checklist which consists of 18 divisions, and each division consists of a number of items.(See Appendix I) It covers the most important aspects of the construction industry, which has a major impact on safety.

Each division will have a certain weight depending on its importance. The weighting was established by surveying five people who have a great knowledge in construction safety and the collected data were averaged. Each item within a division has a score from 0 to 100 depending on the adequacy and availability of that item. Subsequently, the division average is calculated utilizing only the applicable items within that division. The average of each division will be multiplied by its weight to determine the value of the division. Then the overall values of all divisions will be added together to give the final score of the site safety level of the project, which will have a maximum value of 100. Note that only applicable items and divisions will be included in the calculations. The others will be disregarded.

Based on the site safety level, projects could be related as follows:

Table 3.1: Project Rating

From	To	Rating
0	59	Poor
60	69	Fair
70	79	Good
80	89	Very good
90	100	Excellent

The research objectives will be achieved as follows:

1. Objective #1: (Site Safety Level).

The data are collected through a field survey utilizing a checklist. Then the data is screened and the answers to each question are counted. Subsequently the answers to the questions will be put in a graph to determine their tendency.

2. Objective #2: (Correlation Between Safety & Accident Rate)).

Accidents, from the start of construction of each project up to the date of inspection, are identified whether they are lost-day injuries or doctor cases. Then the accident rates are calculated for each project (see Appendix III) and compared to the safety level of each project.

The lost-day injuries are injuries that put a worker off the job for a certain period. On the other hand, doctor cases are injuries that require professional medical attention after which but employees can go back to work immediately.

3. Objective # 3: (Identifying the Effect of Middle Management Practices on Safety).

This objective was achieved by answering a separate questionnaire regarding the management role in the safety program and how the project manager/engineer in the site perceived it. These questions were answered by the project manager/engineer while performing the checklist survey in the field and they addressed the following responsibilities:

- Assigned safety officer on the project
- Job schedule
- Planning meetings
- Safety meetings
- Safety accountability
- Recruiting experienced workers

- training new workers.

Each question has five multiple-choice answers:- always, frequently, sometimes, rarely and never. These answers are assigned values of 25, 20, 15, 10 and 5 respectively. The answers to a particular question collected from all projects are correlated to the accident rate for all projects.

3.3 QUESTIONNAIRE

There is a total of twenty-two questions in this research.(See Appendix II) Some of these questions were designed to have only one expected answer. The rest have five multiple-choice answers. The first type of these questions was used to determine the size of the project in order to classify it as a large, medium or small project. Furthermore, this type of questions was used to determine the period, number of employees, and number of hours worked per week. This information was necessary for the accident rate calculations.

The multiple-choice questionnaire was designed to be simple and answered quickly. Hence this questionnaire was answered on site by the project manager/engineer. These questions were devised to cover those areas which were felt to have a great deal of influence on job safety in the construction industry. These questions address middle management involvement in safety since this is affected by the company policies on safety. The responses to these questions were later compared with the accident rates.

3.4 INTERVIEW PROCEDURE

The author usually contacted the project manager or engineer by telephoning the home office of the company. He usually introduced himself, then stated the purpose of his call and explained the nature of his research. It is notable that only a few people were uncooperative and rejected participation in this research during the phone conversation. Arrangements were made two to three days in advance for a convenient time and place to conduct the site visit and the interview.

All interviews were conducted on site. The author usually introduced himself to the project manager and stated briefly the purpose of his research. Then he submitted the questionnaire to the project engineer/manager. In every interview, it was pointed out that honest replies to the questions were essential to the success of the research. It was also stressed that all comments would be confidential and that the results of this research would not be used to penalize these companies in the future.

After the questionnaire was answered, the author and the project manager toured the project. While touring the project the author usually filled in the inspection checklist which was used to determine the safety level of each project.

The length of the interviews and the tours in the projects varied greatly, depending on the size of the project. The shortest took about forty-five minutes and the longest two and a half hours.

CHAPTER 4

Inspection Checklist

(Saudi Aramco Construction Safety Manual, 1993)

The checklist consists of the following eighteen (18) divisions:

4.1 SITE LAYOUT & HOUSEKEEPING

Items to be considered under site layout and housekeeping include the following:

4.1 .1 Site Layout

The site layout must be planned before any work is started. This will assist in making the job easier and more efficient, thus increasing productivity and profit.

4.1.2 Site Accommodation

This includes shacks, storage huts, compounds, racking areas, lock-up boxes, office buildings, etc.

4.1.3 Adequate Access Roads

Access roads should be kept clear and unobstructed at all times.

4.1.4 Project Signs

Project signs should be erected at the main entrance to the construction site and other sites, i.e., office, lay-down yard, fabrication yard, etc., as designated by the company representative.

4.1.5 Safe Means of Access and Egress

Safe means of access and egress to be provided on site wherever employees are likely to go; these must be kept clear and unobstructed at all times.

4.1.6 Parking Facilities

Parking places should be provided in clearly defined areas on site.

4.1.7 Drainage

The site should have good drainage and be graded in such a way that water does not pool up during construction.

4.1.8 On-Site Vehicle/Heavy Equipment Paths Vs Pedestrian Paths

Pathways for workmen must be clearly marked and distinct from vehicular travel routes on site.

4.1.9 Sand

In sand-dune areas that might lie adjacent to or around a construction site, consideration should be given to the movement or build-up of sand.

4.1.10 Fire Prevention

Suitable fire-extinguishers must be readily available on site. The area around fire-extinguishers or hydrants must be kept clear so that they are readily accessible in case of emergency. Extinguishers must be regularly inspected and maintained. Site personnel must be trained in the use of fire fighting equipment.

4.1.11 Site Illumination

Adequate lighting must be provided in all areas of the job site.

4.2 PERSONNEL PROTECTIVE EQUIPMENT

4.2.1 Head Protection

Safety hats or helmets are rigid headgear made of materials designed to protect the head from impact, flying particles, electric shock, etc. Each helmet consists of a shell, a suspension cradle, and a chin-strap.

Employees working in areas where there is danger of head injury from impact, from falling or flying objects, or from electrical shock and burns, should be protected by protective helmets.

The suspension cradle gives a helmet its impact distribution qualities. It is therefore, essential that it be properly adjusted to the wearer's head so there is a gap of at least one and a half inches between the top of the suspension cradle and the helmet shell.

Other equipment such as ear muffs, welders shields, etc., can be obtained to fit on helmet shells. Holes should not be drilled into the helmet to facilitate the use of such equipment as this can seriously impair both the mechanical strength and the electrical resistance of the helmet.

A safety helmet should be worn by all persons at all times when on a construction job site or whenever there are overhead hazards. Metal hard hats do not afford proper impact or electrical protection. Therefore, they are not advisable.

4.2.2 Eye and Face Protection

Protection of the eyes and face from injury by physical or chemical agents or light radiation, is of prime importance in an industrial environment. The type of protection selected will depend on the hazard, but it should be borne in mind that all eye protection and most face protection devices must be considered as optical instruments. They must be selected, fitted, and used with regard to both the type of hazard and the optical condition of the user. The wearing of contact lenses is not recommended in areas where eye protection is required.

4.2.3 Hand Protection

The kind of gloves used depends primarily upon the material or equipment being handled and can be resistant against one or more of the following: heat, acid, caustic, slipping, wear, fire, oil, sharp edges, general wear-and-tear, cold, etc. Gloves should not be used near moving machinery as they can be caught and trap the hand before it can be withdrawn from the glove.

4.2.4 Foot Protection

Safety footwear is available in many styles, with special soles to resist oil, abrasion, heat, and other abuses to which the footwear may be subjected. Comfort is particularly important for the wearer, so safety footwear must fit properly.

4.2.5 Hearing Protection

Increasing attention is being paid to the problem of excessive noise in industry. Noise can be defined as "any unwanted sound". The intensity of noise is commonly expressed in terms of decibels (dB) and measured by a sound-level meter. Medical authorities state that continual exposure to noise levels above 90 dB for an eight-hour day, five-day work week may endanger a person's hearing. The safe period of exposure to a noise level is inversely proportional to the level of the noise.

4.3 FIRE PREVENTION

4.3.1 General

Each contractor has an obligation to provide and maintain adequate, easily accessible fire-extinguishers on the job site. The contractor should consult with the local Fire Protection Unit for advice on selection of such equipment. There are three types of fire-extinguishers normally found on construction sites: water, carbon-dioxide and dry-chemical types. Contractor personnel should be aware of the fire-fighting equipment available on site and be familiar with its use.

4.3.2 Water-Type Fire Extinguisher

Water extinguishers should be available around sites where there will be Class "A" material, such as wood, paper, waste material, or packing crates. The typical portable water extinguisher comes in a 9.5-liter (2-1/2 gallon) size.

4.3.3 Carbon-Dioxide Type Extinguisher

The carbon-dioxide (CO_2) type extinguisher is normally used for controlling electrical fires. These fires take place in motors, switch-gear, and so forth, and are usually very easily controlled by de-energizing the circuits that supply the power. The advantage of using CO_2 in this particular instance is that it leaves no residue in the mechanisms of the electrical equipment and, therefore, does not further contribute to the damage.

However, a CO_2 extinguisher should never be used in enclosed areas where people are present, because the gas displaces oxygen from the immediate environment. When the oxygen level in the environment is reduced sufficiently to put out a fire, the oxygen level is also incapable of supporting human life.

4.3.4 Dry-Chemical Type Extinguisher

A dry-chemical type extinguisher is normally used in controlling Class "B" fires in flammable liquids. A dry-chemical extinguisher normally comes in portable 9-kilogram and 13.6-kilogram sizes. Some dry-chemical extinguishers today have a powder which is effective in controlling Class "A", "B", and "C" fires. This multipurpose ABC powder gives this particular fire extinguisher a good chance of controlling any type of fire involving wood, petroleum liquid, or electrical equipment.

4.4 TRANSPORTATION

4.4.1 General

Drivers should comply with all Saudi Arabian Government traffic signs.

All vehicles should be parked correctly and/or in designated parking areas. Parked vehicles should not obstruct other vehicles, roadways, accesses or fire-hydrants.

4.4.2 Vehicle Inspection Checklist:

1. The vehicle number, company name, current inspection stickers and license plate (front and back) must be in place.

2. Seat belts are mandatory for all vehicle occupants.

3. Two reflective warning triangles should be in each vehicle.

4. Windows and windshield must be clean and free of cracks or damage. The glass must be in good condition. The windows must open and close properly.

5. All lights (high- and low-beam headlights, tail-lights, dash-lights, stop-lights, turn-signal lights, and the rear-license-plate light) must be in working order. When fog-lights (front and rear) and clearance lights have been provided, they must be also be in good working order.

6. All brakes (foot- and hand-brakes) must be in good working order. Check the foot- and hand-brake mechanism for correct operation.

7. The automatic transmission must be in good operating condition and should shift into the parking position correctly.

8. Springs and shock-absorbers must be in good condition, with no alignment or control problems.

9. There should be no excessive movement of the steering-wheel and no signs of damage. Steering knobs and loose coverings are prohibited.

10. Tires should have no breaks in the tire casing or exposed fabric and must be inflated to the correct air pressure.

    If the treads show any signs of wear like bare patches, this could indicate defective steering, springs and/or shock-absorbers.

11. Check the sheets for rim damage. Make sure the wheels are not buckled or out of alignment and wheel lug-nuts are in place and secure on the rim.

12. If the vehicle is fitted with a trailer, the coupling must be intact and working correctly. The trailer should have safety coupling chains, rear brake lights, turn signals, tail lights and rear license plate lights.

13. Make sure that the inside and outside rear-view mirrors are clean, adjusted, secured and undamaged.

14. Check that the windshield-wiper blades are in good condition, and operate properly. Inspect the rear-window wiper, if fitted.

The windshield washer should work properly and there should be water in the water container.

15. The speedometer should be in good working order.

4.5 EXCAVATION

4.5.1 Shoring Protective Systems

As soon as an excavation reaches a depth of 1.2 meters or soil banks are greater than 1.5 meters, suitable shoring must be installed or the side sloped back to a safe angle. Shoring may be of timber or any other suitable material, such as steel-sheet piling.

The determination of the angle of slopes, benches, or the choice and design of other protective systems must be based on evaluation of pertinent factors such as: type of soil, depth of cut, possible variations in water content of the material while the excavation is open; anticipated changes in materials from exposure to air, sun, or water; loading imposed by structures, equipment, overlying material, or stored material; and vibrations from equipment, blasting, traffic, or other sources.

Excavations must not be sloped at a gradient greater than one and one-half horizontal to one vertical (34 degrees measured from the horizontal).

4.5.2 Inspection

All parts of an excavation, including the shoring, must be inspected every day by a competent person to ensure that there is no danger of collapse and all observations must be noted in the site safety log-book.

4.5.3 Clearance

In order to provide a safe footing at the edge, and to prevent soil falling into an excavation, a clear space at least 0.6 meter wide must be maintained on all sides.

4.5.4 Mechanical Excavator

Men must not be permitted to work underneath loads or in places where they could be struck by any part of a mechanical excavator.

4.5.5 Walkways

Where employees, equipment, or members of the public are required or permitted to cross over an excavation, a close-planked bridge or walkway with standard guard-rails must be provided and kept clear of excavated materials or other tripping hazards. No sidewalk must be undermined unless properly shored.

4.5.6 Access and Egress

Safe means of getting into and out of an excavation must be provided at intervals not exceeding 7.5 meters. Ladders must be placed at an angle of 75 degrees, and extend at least 0.9 meter above the stepping-off point. Ladders must be securely fixed.

4.5.7 Ventilation

Where there is reason to suspect oxygen deficiency or the presence of a hazardous atmosphere in an excavation, gas tests must be carried out by a qualified person. Where necessary, mechanical ventilation must be used, or other appropriate precautions must be taken before men enter.

4.5.8 Emergency Rescue Equipment

(i) Emergency rescue equipment, such as breathing apparatus, a safety harness and line, or a basket stretcher, must be readily available where hazardous atmospheric conditions exist or may develop during work in an excavation. This equipment must be attended by a standby man outside the trench when in use.

(ii) Employees entering bell-bottom pier holes, or other similar deep and confined footing excavations, must wear a harness with a lifeline attached to it. The lifeline must be separate from any line used to handle materials, and must be individually attended at all times while the employee wearing the lifeline is in the excavation. Mechanical devices must be available to lift incapacitated employees from excavations.

4.5.9 Exhaust Gases

Where an internal combustion engine is used in an excavation, special precautions must be taken to ensure that exhaust gases are discharged so as not to be a hazard to men working in the excavation.

4.6 WELDING, CUTTING, AND BRAZING

4.6.1 General

This section outlines the principles involved and the precautions to be taken in gas welding, cutting, and brazing and electric-arc-welding operations.

Welding/cutting are safe operations if carried out in the correct manner. Where equipment is defective or there is no well-arranged, well-lit, or properly ventilated working place, hazards can arise.

4.6.2 Gas Welding: Oxy-Acetylene Equipment and Use

Personnel working with welding equipment must be trained, competent, and provided with personal protection equipment. Welding goggles, helmets, screens, forced ventilation and similar equipment must be provided to all workers and to trainees in the immediate area.

4.6.2.1 Personnel Protection

Helmets, welding hoods, and goggles are necessary to protect eyes and face against heat and the effect of the intense light emitted by welding operations.

Goggles are required to protect the eyes of the welder from pieces of flying slag chips during electric arc-welding. They should be fitted with opaque side pieces. The goggles should also be worn under the regular welding hoods.

Electric welding operations must be effectively screened to prevent nearby personnel from being affected by harmful radiation. Screens should be made from fire-resistant materials or should be suitably treated with a fire-resistant compound. Screens should be designed and placed so as not to restrict the flow of air for ventilation purposes.

Gloves are necessary protection for the hands against heat, sparks, molten metal, and radiation. Leather, suitably reinforced at points of maximum wear, is the material most generally worn. Gloves should be long enough to protect wrists and forearms. When gloves are not long enough, protective sleeves of similar materials should be worn.

Safety boots and leggings are essential to provide effective protection against heat, flying sparks, and falling metal.

4.6.3 Electric Arc-Welding

Arc-welding is a process for joining metals by heating with an electric arc. For arc-welding, two welding leads, the electrode lead and the work lead are required.

4.6.3.1 Voltage

The voltage across the welding arc is normally within the range 20-40V. The voltage supplied, however, needs to be somewhat higher so that means of stabilizing and regulating the arc current can be introduced into the circuit. Using DC, a 60-80 supply will usually suffice. Using AC, an 80-85V supply will suffice although some of the latest techniques need an open-circuit voltage of up to 100V between electrode and work. It should be remembered that a nominal 100V supply has, in fact, a peak voltage of 141V.

For these reasons, DC should be used for welding operations in any situation where the effect of electricity is likely to be extreme, such as in damp and confined spaces (tanks, boilers, etc.)

4.6.3.2 Welding Cables

Welding-cable insulation needs to be abrasion resistant to withstand normal treatment over rough ground and the wear inflicted by foot and vehicular traffic. Where feasible, cables should be additionally protected by stringing them overhead, or by using cable covers. They should be regularly examined for cuts or abrasions to the insulation; damaged cable should not be used. If joints become necessary, standard plug-and-socket coupling should be used. Holders should be unplugged when not in use. Splices are not allowed in welding cables.

4.6.3.3 Electrodes

Electrode-holders should be constructed to accommodate all sizes of electrodes. They should be equipped with an ejector for hot, spent stubs.

A shield should be fitted between the electrode-holder and the handle to prevent live elements from being touched. The handle itself should be made of non-flammable insulating material and be free from joints or holes.

4.6.3.4 Auxiliary Power Outlets

Most welding machines are furnished with an alternator which produces 3 KVA of 115 and 230 volts. As a safety factor, all power hand-tools which are not double insulated should be grounded to the welder frame. Ground-fault interrupters should be required, where power output exceeds 5 KV. Placards should be placed on the welding machine.

4.7 COMPRESSED GAS

4.7.1 General

Oxygen (O_2) is odorless. It can promote rapid combustion; therefore, grease and oil should never be used near oxygen as this could cause fire.

Oxygen cylinders or apparatus should not be handled with oily hands or gloves. A jet of oxygen should never be permitted to strike an oily surface, greasy clothes or enter fuel, oil or other storage tanks.

Acetylene (C_2H_2) has a distinct odor often likened to that of garlic or sour apples. It is combustible when mixed with air over a wide range of percentages (2.5% - 81%). Acetylene burned with oxygen can produce a higher flame temperature than any other commercial gas.

Acetylene becomes unstable at pressures above 103 kpa, which means it may explode. Under no conditions should acetylene be generated, piped (except in approved cylinder manifolds) or utilized at a pressure in excess of 103 kpa. Inside the cylinder, acetylene is dissolved in acetone to prevent internal explosion; therefore, it is essential that acetylene cylinders be stored, handled, and used in the vertical position to prevent the liquid acetone from escaping and damaging the valves and other equipment.

4.7.2 Storage of Cylinders

Cylinders should be stored in a safe, dry, well-ventilated place prepared and reserved for that purpose. Flammable substances, such as oil and volatile liquids, or corrosive substances should not be stored in the same areas. Oxygen cylinders and flammable gas cylinders should be stored separately, at least 6.6 meters apart or separated by a fire-proof, 1.6- meter high partition.

All storage areas should have Arabic and English "No Smoking Permitted" signs prominently displayed.

All cylinders should be chained or otherwise secured in an upright position. To prevent rusting, cylinders stored in the open should be protected from ground contact, extremes of weather, or contact with water. Valve caps should be kept in place when cylinders are not in use. Flammable substances should not be stored within 50 feet of cylinder storage areas.

Cylinders should not be stored at temperatures exceeding 54°C (130°F). Accordingly, they should not be stored near sources of heat such as radiators, or near highly flammable substances like gasoline. Cylinders must be stored out of the direct rays of the sun, in protective enclosures or sun shelters.

Cylinder storage should be planned so that cylinders will be used in the order in which they are received from the supplier. Empty and full cylinders must be stored separately, with empty cylinders plainly marked as such, to avoid confusion. Empty cylinders should be segregated according to the type of gas they have held.

4.7.3 Handling of Cylinders

Serious accidents may result from the misuse, abuse, or mishandling of cylinders.

Cylinders should never be lifted by their valves since the valves are not designed to take such stress. When the cylinder is not in use, the valve should be protected with the valve cap.

All valves must be fully closed before a cylinder is moved. Unless a trolley or special carrier is used, regulators and hoses should be detached from the cylinders before they are moved.

If cylinders are to be lifted by a crane, specially designed bottle-holders with lifting-eyes should be used. Chain and wire-rope slings can allow cylinders to slip. Where a trolley is to be used for slinging, its base should be strong enough to take the weight of the cylinders.

Cylinders in transit on vehicles should have valve caps in place and be firmly secured to prevent movement. Cylinders should be secured to avoid any violent contact. Loading and unloading should take place carefully. Cylinders should not be dropped, thrown, dragged, used as rollers, or as a support. No damaged or defective cylinder should be used.

4.7.4 Confined Spaces

It is vital that forced ventilation be maintained in confined spaces at all times. Air-line respirators may be needed for men working inside such places. No gas cylinders should ever be allowed into such areas The hoses and equipment used inside must be in excellent condition.

Where work in confined spaces has to take place over several days, the hoses and equipment should be taken outside overnight in case any leakage should occur, resulting in a build-up of gas.

4.8 SCAFFOLDING

4.8.1 Foundations

A sound base is essential; therefore, the ground or floor on which a scaffold is going to stand must be carefully examined. Sand or made-up ground may need compacting to ensure there are no cavities. Such bases as floors, roofs, etc., may need shoring from underneath.

Scaffolds, including components, should be capable of supporting without failure at least 4 times the maximum intended load.

Timber sills (not scaffold planks), which must be at least 23 centimeters wide by 3.8 centimeters thick, will be required to spread the load on sand, made-up ground, asphalt pavement, wooden floors, and slippery surfaces. A sill should extend under at least two posts.

Where scaffolding is erected on a solid bearing, such as rock or concrete, small timber pads may be used in place of sills and nailed to prevent the baseplates sliding off.

Concrete blocks, barrels, and other loose or unsuitable material should not be used for the construction or support of scaffolding.

If used to compensate for variations in ground level, the screw jack should not be adjusted to more than two-thirds of the total length of the thread. The base plate should be of a type approved for supporting scaffolding posts according to the manufacturer's specifications.

4.8.2 Posts

Posts should be pitched on 15 cm-square steel baseplates and at least 0.64 centimeters thick. Joints in posts should be staggered, i.e., joints in adjacent posts should not occur in the same lift. All posts should be vertical.

The inner row of posts should be placed as close as possible to the face of the building or structure. To avoid projections, the posts may be up to 41 centimeters away from the wall or structure as necessary, provided that, where there is room to do so, the gap between the wall or structure and the inner posts is closed with planks on extended board bearers. The outer row of posts should be positioned from the inner row of posts, depending on the load requirements of the scaffold, and the working platform should be fully decked out.

4.8.3 Runners

Runners should be securely fixed to posts with standard couplers and should be horizontal. Joints in runners should staggered, i.e., joints in adjacent runners should not occur in the same bay. Runners should be secured end-to-end by sleeve couplers, not by joint pins.

Runners should be vertically spaced no more than 2.0 meters apart to give adequate headroom along the platforms.

4.8.4 Bearers

Bearers should be installed between posts and securely fixed to the posts bearing on the runner coupler and they should be secured with standard couplers. When coupled directly to runners, the coupler must be kept as close to the posts as possible. These bearers must remain in position as they are a structural part of the scaffold.

4.8.5 Board-Bearers

Board-bearers should be installed between bearers to accommodate differences in plank lengths. Board-bearers should be secured to the runners between bearers, where necessary, in order to support platform units (planks). These may be removed when no longer required to support platform units.

4.8.6 Bracing

Cross bracing should be installed across the width of the scaffold at least every third set of posts horizontally and every fourth runner vertically. Such bracing should extend diagonally from the inner and outer runners upward to the next outer and inner runners. These braces should be fixed to the runners with standard couplers as close to the posts as possible. Where such a fixing is impracticable, adjustable couplers may be used to fix the braces to the posts.

Longitudinal diagonal bracing should be installed at an approximately 45-degree angle from near the base of the first outer post upward to the extreme top of the scaffold. Where possible, such bracing should be duplicated at every fifth post. On short but high runs, diagonal bracing should be installed at an angle of 45 degrees from the base of the first outer post to the last outer post and should alternate directions to the top of the scaffold. When bracing cannot be attached to the posts, this bracing may be attached to the runners, as close as possible to the posts. Only standard couplers or adjustable couplers may be used. Joints in braces should be made with end-to-end or parallel couplers.

Temporary rakes (inclined load-bearing tube supports) brace the scaffold against the ground when setting out. These rakes are replaced by permanent braces when the scaffold has been plumbed, leveled and tied. Rakes must be secured with proper couplers at the scaffold and coupled to a ground stake.

4.8.7 Ties

It is essential that all scaffolds, with the exception of certain tower and mobile scaffolds, be securely tied to the building or structure throughout their length and height to prevent movement of the scaffold either towards or away from the building or structure. This should be done by connecting a tie-tube to both runners or posts and coupling this to a two-way tie or column box-tie assembly.

Where the foregoing is impracticable, tubes may be securely wedged between opposing surfaces on the building or structure by the use of reveal pins and coupled to the tie tubes. Where reveal ties are used, they should not exceed 50% of the total number of ties. Two-way ties or column box-ties should be evenly distributed over the scaffold area. To ensure the security of reveal ties, it is necessary to check frequently for tightness.

Ties should occur at the top of the scaffold and at least every 7.9 meters vertically and 9.1 meters horizontally and at each end of the scaffold. All tie assembly connections should be made with standard couplers.

4.8.8 Platform Units

All platform units (i.e., planks, fabricated decks, etc.) should be close-planked with, whenever practicable, each plank resting on at least three supports. Planks should extend over their end-supports by not less than 15 centimeters and not more than 30.5 centimeters.

Supports for scaffold planks should be spaced with due regard to the nature of the platform and the load it will bear.

Except on platform units adjacent to the surface of a cylindrical or spherical structure, planks should be laid flush.

Planks should be secured in position to prevent displacement by high winds.

Adequate space for men to pass in safety should be provided and maintained wherever materials are placed on platform units or if any higher platform is erected thereon.

Platform units should be kept free of unnecessary obstructions, materials, and projecting nails.

Platform units which have become slippery with oil or any other substance should be cleaned, or otherwise removed and replaced.

Gradients in platform units should not exceed 1 vertical to 4 horizontal and stepping cleats at 0.3-meter intervals should be provided.

All platform units should be close-planked for the full width of the scaffold structure.

4.8.9 Guardrail Systems and Toe boards

Guardrail systems (consisting of toprails and midrails) and toeboards should be installed at all open sides and ends of all scaffolds and supports on no more than 3 meter centers to prevent men or materials from falling a distance of more than 1.8 meters. Toprails should be no less than 0.91 meters and no more than 1.14 meters above the working surface; midrails should be installed equidistant between the working surface and the toprail. Toeboards should not be less than 10 centimeters high by 2.5 centimeters thick. Guardrail systems and toeboards should be securely fixed to the inside of posts to withstand a large lateral thrust.

Safe landings should also be provided at the top of all ladders. Rings should be eliminated above the landing level, and side-rails should extend 90 to 105 cm above the landing for mounting and dismounting. Where multiple ladders are required, solidly decked platforms should be provided. Guardrails, intermediate rails and toeboards should be erected on the outside edges and exposed sides of the platform.

4.8.10 Access

Access to a working platform is best achieved by providing a separate ladder tower or a cantilevered access platform so as not to obstruct the working platform and to minimize the risk of persons falling through gaps in the guardrail system or platform units. Access must be provided to working platforms.

4.9 HAND TOOLS AND POWER TOOLS

4.9.1 General

Hand tools are those tools for which the hand provides the motive force, e.g., picks, shovels, axes, crowbars, wrenches, saws, chisels, hammers, screwdrivers, etc. It is the contractor's duty to ensure that his workmen are properly instructed in the selection and use of the correct tool for the job. Tools constructed of good quality materials should always be used. Poor quality tools increase the risk of accidents and also reduce the efficiency of work.

Power tools, however, allow many jobs to be carried out more efficiently and with greater speed and accuracy. The correct use of power tools can only be achieved by the proper training of workmen, by proper maintenance, and by adequate site supervision. Many accidents have occurred because unskilled and untrained labor has been allowed to operate power tools in an incorrect manner.

4.9.2 Hand tools

4.9.2.1 Cleanliness

The contractor should ensure that hand tools are regularly cleaned and, where necessary, lightly oiled as a protection against corrosion.

4.9.2.2 Repair and Storage

All hand tools should be regularly inspected before and after use, and before storage. If wear or damage is observed, the tool should be withdrawn from use for repair or disposal. The contractor should ensure that the storekeeper maintains a record of all tools issued, repaired, and withdrawn from use. Proper racks and boxes should be provided for the storage of hand tools.

4.9.2.3 Selection

The majority of accidents are caused by using an incorrect tool for the job. It is essential that the correct type, size, and weight of tool should be decided upon before any work is carried out.

4.9.2.4 Electrical Risks

All uninsulated metal tools are conductors of electricity. Where work takes place on or near electrical operations, only properly insulated and non-conductive tools should be used. Insulation should be checked at regular intervals by a competent electrician.

4.9.2.5 Individual Hand Tools, Precautions

4.9.2.5.1 Screwdrivers

It is essential that a screwdriver has the correct size of tip to fit the slot of the screw. If the screwdriver fits the screw correctly, the screw will be drawn into the correct position without unnecessary force being applied. Over-tightening of screws can lead to possible hand injury if the screwdriver slips.

Screwdriver shanks are not designed to withstand the twisting strain applied by a pair of pliers or more grips in order to obtain additional leverage. On no account should screwdriver handles be subjected to blows from a hammer or similar instrument.

Screwdrivers should never be carried in the pockets of overalls or other clothing. A screwdriver can produce a serious wound.

4.9.2.5.2 Hammers

It is essential that the right kind of hammer be selected for the job. Hammer handles should be made from smooth timber or be made of an integral head and shaft of steel. Hammer heads should be secured to wooden handles with proper wedges.

4.9.2.5.3 Chisels

Cutting edges should be kept sharp at all times, and the original shape and angle should be maintained. Re-sharpened cold chisels should be suitably hardened and tempered to maintain them in a safe working condition. The chisel heads will mushroom in use. As soon as mushrooming is observed, the head should be reground with a slight taper around the edge to prevent chipping and reduce the tendency to re-mushroom. Eye protection should be worn at all times when a cold chisel is used.

On jobs where it is necessary to use a sledge-hammer for striking the chisel, the chisel should be held by a second person using a pair of tongs.

Wood chisels should also be maintained in a sharp condition so that minimum pressure is exerted when making a cut. If the chisel is to be struck, only a wooden or soft mallet should be used.

4.9.2.5.4 Picks and Shovels

Picks and shovels should be maintained in a serviceable condition at all times. Shovel blades should not be allowed to become blunt, turned, split, or jagged. Pick-head points should be kept sharp and heat-treated so that the metal wears down in use and does not splinter or shear off. Shafts of picks and shovels should be kept free from cracks and splinters.

4.9.2.5.5 Spanners and Wrenches

Only spanners and adjustable wrenches of the right size should be used. When possible, use box-end rather than adjustable wrenches. The jaw should first be checked for any sign of opening out or splitting. Spanner and wrench lengths are graded to provide sufficient leverage on the nuts for which they are designed. Improvised extension to these tools is an unsafe practice and may cause the bolt tread to strip or cause shearing of the bolt. On no account should ordinary wrenches be struck by a hammer when tightening nuts. For heavy work of this nature, a properly designed slugging wrench should be used.

4.9.2.5.6 Pipe Wrenches

Pipe wrenches must be large enough for the job, the jaw teeth must be kept clean and sharp, and the knurl, pin, and spring should be kept free from damage. Pipe wrenches should never be struck with a hammer, nor should they be used as a hammer.

4.9.2.5.7 Pliers

Pliers should only be used when there are no other tools for the job. They are meant only for gripping around objects and should not be used as a wrench.

Care should be taken when cutting soft metal with pliers to ensure the scrap portion does not fly off and cause injury. If wire is cut under tension, then long handled pliers should be used. Where pliers are used for electrical work, they must be fitted with insulated handles. All pliers should be kept free from dirt and grit, and the movable parts should be lightly lubricated.

4.9.2.5.8 Jacks

Jacks should be marked with rated capacity and must be heavy enough and strong enough to raise and maintain the load. They should be placed on a firm and solid support, and the load should be positioned on the center line of the jack.

Once a load has been raised, it must be shored or blocked. The jack should never be relied upon to hold the raised load in position by itself. Extreme care should be taken when working under or near a raised load.

4.9.2.5.9 Hacksaws

The correct type of blade should be selected to suit the material to be cut. The blade should be set in a hacksaw frame so that the teeth are pointing in the forward direction, and sufficient tension should be applied to ensure the blade is maintained right.

4.9.2.5.10 Handsaws

Many kinds of woodworking handsaws are available, and care should be taken to select the correct saw. All handsaws should be regularly examined to ensure that the saw teeth are properly set so as to avoid binding in the timber which can cause the blade to buckle. The teeth should be kept sharp, clean, and lightly oiled. When the saw is not in use, the blade should be protected by a slotted piece of timber or a sheath.

Two-man saws should be operated by pulling only. The kerf should be kept straight to avoid the blade buckling. The kerf should be wedged open to prevent the timber from pinching the blade.

4.9.3 Power Tools

4.9.3.1 Quality

The contractor should ensure that all portable power tools do not exceed a 125-volt rating, are manufactured of sound materials, and are free from defects and properly grounded.

4.9.3.2 Repair and Storage

All portable power tools should be stored in clean, dry conditions. The contractor should provide a schedule of systematic inspection and maintenance for all power tools. All tools should be returned to the storekeeper at the completion of each individual job. Power tools must not be left lying around the job site where they could be damaged.

4.10 CARTRIDGE OPERATED TOOLS

4.10.1 General

Cartridge operated tools have a great advantage in that they can be used in almost any situation without the inconvenience of trailing leads or hoses. However, it is essential that these tools be operated only by properly trained personnel who are over 18 years of age.

4.10.2 Storage

Safe and secure storage for cartridges and tools must be provided on the job site. Storage must be fire-proof, dry, must be capable of being locked and should be sited in a clear, but easily accessible location where constant supervision can be maintained.

Cartridges and tools must not be stored together. A storage unit providing positive physical separation of cartridges and tools (i.e., a wall or partition) is required.

Warning notices must be posted where cartridges are stored: "DANGER - NO SMOKING Cartridge Storage"

Ventilation must be provided in the store. Cartons of cartridges must not be stacked against the wall and ventilation spaces must be left around the cartons. Only one carton of each strength cartridge should be open at any one time. All empty cartons, and intermediate packing, must be removed at once.

Tools must be stored in their carrying cases. No loose cartridges must be in the carrying cases; all cartridges must be in their color-coded boxes.

Only authorized personnel must be allowed access to the store.

4.10.3 Selection and Training of Personnel

No person may operate, clean, maintain, or repair any cartridge tool without possessing a certificate of competency, issued by an accredited tool vendor or manufacturer's representative, which identifies the particular model that the person is qualified to handle.

Personnel for training must be selected with the following points in mind:

1. Must be over 18 years of age.

2. Must be physically fit and have full use of both hands and both eyes.

3. Should ideally be a tradesman, e.g., plumber, mason, electrician, joiner/carpenter, etc.

4. Storemen may also need to be trained if they are required to clean and maintain the tools.

Training, both theoretical and practical, must be given by a competent instructor. The training must follow the manufacturer's instructions as contained in the handbook of each particular model.

4.10.4 Personal Protective Equipment

Eye protection should be worn by the operator and his assistant whenever using the tools. Goggles must be of a satisfactory standard designed to withstand high speed impacts and/or, penetrations.

Ear-muffs will be available for use at any time and should be used in confined spaces.

Safety-belts may be required in certain situations where the recoil from the tool could cause an operator to loose his balance.

4.10.5 Issue and Returns

Contractors will ensure that a full register of the serial numbers of each tool is made and kept up to date.

A long inventory system of issuing and returning cartridges and tools against signatures must be initiated and maintained.

Only personnel in possession of a user certificate will be allowed to withdraw tools or cartridges from the store.

Only the minimum number of cartridges required for that particular shift's operation should be issued at any one time.

Cartridges and tools must not be left on the job site at lunch break or at end of shift but must be returned to the store for safekeeping.

Any loss, either of tools or cartridges, must be reported, at once, to the project proponent.

4.10.6 Use

No person may operate, clean, maintain or repair any cartridge tool without possessing a certificate of competency which identifies the particular model that person is qualified to handle.

The manufacturer's operating instructions must be followed at all times.

Cartridges are manufactured in different calibers and strengths. There are three sizes: .25 short, .27 short, and .27 long; and, four strengths, as follows:

Table 4.1: Cartridges Powers & Color Coding

Power Level	Number	Color Code	Letter Code
Low	3	Green	L
Low/Medium	4	Yellow	LM
Medium/High	5	Red	MH
Extra High	6	Purple/Black	EX

It is, therefore, imperative that one determine the correct size and strength of the cartridge required for the tool and for the material on which the fixture is to be made.

Using a cartridge which is too powerful could cause a ricochet or a spalling or fracture of the material.

The following General Safety and Operating Rules are common to all types of tools:

1. Tools should not be loaded with a cartridge until just prior to the intended firing time. When loading a tool, point it away from you and anyone else. Never walk around with a loaded tool; load it where you are working. Never leave the tool loaded when not in use. Loaded tools should not be left unattended.

2. Tools should not be operated without the end of the barrel hard against the fixing surface.

3 All tools should be used with the correct shield, guard, or attachment recommended by the manufacturer.

4 Fasteners should not be driven into very hard or brittle materials including, but not limited to, cast iron, glazed or hollow tile, surface hardened steel, glass blocks, terra cotta, marble, granite, slate, etc.

5. Driving into soft or easily penetrable materials should be avoided unless materials are backed by another material that will prevent the pin from passing completely through and creating a flying missile hazard on the other side. Careful inspection of all materials should be made before deciding on the use of a cartridge tool.

6. No pins should be driven into a spalled area caused by an unsatisfactory shot, or into any existing hole in the material. Care should be taken to ensure that the new fixing is at least two inches away from any previous hole, and a similar distance from any welded joint.

7. Pins must not be fired into corner bricks, mortar joints, and must be at least 10 cm away from the edge of concrete or brick work and 1.5 cm from the edge of steel.

8 Ensure that the correct strength cartridge is used for the pin, fixing and material involved. For the first, or test firing, use the weakest cartridge. Too strong a cartridge may result in over-penetration, or the fastener may rebound or ricochet.

9 The tool must be held at right angles to the job when firing.

10. In the event of a misfire, the tool should be re-triggered without moving the tool from the work face. If the shot again fails, then the tool must be held firmly in the firing position for at least 30 seconds to allow for a possible "Hang Fire" in the cartridge. The removal of the misfired cartridge must be as made in accordance with the manufacturer's instructions. Do not use nails, knives, etc., to pry the cartridge loose.

11 Recoil from firing can throw an operator off balance, especially when he is working from ladders or scaffolds. Care must be taken to ensure that the operator has a secure and safe work area. Safety-belts should be used if necessary.

4.11 CONCRETE FORMWORK

4.11.1 General

Formwork and shoring should be designed, erected, supported, braced, and maintained so that it will safely support all vertical and lateral loads that may be imposed upon it during the placement of concrete.

Personnel should not be allowed under, or in close proximity to, the formwork during pour operations.

Personnel not engaged in the pour operation should stay clear of the pour area. A clear area should be maintained at 1-1/2 times the highest point of the form work.

Drawings or plans showing the jack layout, formwork, shoring, working decks, and scaffolding, should be available at the job site.

Stripped forms and shoring should be removed and stockpiled promptly after stripping, in all areas in which persons are required to work or pass. Protruding nails, wire ties, and other form accessories not necessary to subsequent work should be pulled, cut, or other means taken to eliminate the hazard.

Imposition of any construction loads on the partially completed structure should not be permitted unless such loading has been considered in the design and approved by the engineer-architect.

4.11.2 Vertical Slip Forms

The steel rods or pipe on which the jacks climb or by which the forms are lifted should be specifically designed for the purpose. Such rods should be adequately braced where not encased in concrete.

Jacks and vertical supports should be positioned in such a manner that the vertical loads are distributed equally and do not exceed the capacity of the jacks.

The jacks or other lifting devices should be provided with mechanical dogs or other automatic holding devices to provide protection in case of failure of the power supply of the lifting mechanism.

Lifting should proceed steadily and uniformly and should not exceed the predetermined safe rate of lift or concrete cure.

Lateral and diagonal bracing of the forms should be provided to prevent excessive distortion of the structure during the jacking operation.

During jacking operations, the form structure should be maintained in line and plumb.

All vertical lift forms should be provided with scaffolding or work platforms completely encircling the area of placement with intermittent tie breaks to ensure that superimposed loads on the scaffold/work platforms cannot pull down the entire scaffold works.

4.11.3 Tube and Coupler Shoring

Couplers (clamps) should not be used if they are deformed, broken, or have defective or missing threads on bolts, or other defects.

The material used for the couplers should be of a structural type such as drop-forged steel, malleable iron, or structural-grade aluminum. Gray cast-iron should not be used.

When the erected shoring towers are being checked with the shoring layout, it should be noted that the spacing between posts should not exceed that shown on the layout, and all interlocking of tubular members and tightness of couplers should be checked, also.

All baseplates, shore-heads, extension devices, or adjustment screws should be in firm contact with the footing sill and the form material and should be snug against the posts.

4.12 CRANE AND LIFTING DEVICES

4.12.1.1 Competent Persons

A competent person is a person who, by possession of a recognized pertinent degree or certificate of professional competence , or who by extensive knowledge, training and experience has successfully demonstrated the ability to solve or resolve problems relating to safe crane operations and procedures (e.g. Rigger Technician, Crane and Rigging Specialists, etc.). A competent person should supervise all lifts.

4.12.1.2 Crane Operations (General Requirements)

Before beginning any crane operation, the supervisor and operator should complete the pre-operation checklist. A lift plan required as a part of this procedure must provide the following information:

1. Crane radius
2. Boom length
3. Safe working limits of the crane (load chart)
4. Weight of the load
5. Ground and site conditions
6. Placement of the crane
7. Swing and tail clearances
8. Necessary communications to be used
9. Explanation of hand signals
10. Rigging hardware

11. Rigging sketch for critical or hazardous lifts
12. Rated capacity of rigging components
13. Sling angles
14. Strain calculations
15. Wind velocity
16. Load-moment indicator
17. Other.

4.12.2.1 Safe Working Load (SWL)

Slings and other rigging equipment must be constructed according to a recognized standard.

The safe working-load of rigging equipment is the maximum load which the equipment should be subjected to; this load should never be exceeded.

Before use, all new equipment should be subjected to a proof load-test by the manufacturers and certified. The safe working-load and serial number should be clearly marked on the sling and the lifting gear, either by tagging, stamping, engraving, or embossing. Riggers should not use lifting gear unless the safe working-load is clearly visible.

4.12.2.2 Chain Slings

4.12.2 .2.1 Grade

Each grade of chain should be clearly tagged by the manufacturers, and riggers should be trained to look for the safe working-load marked on each sling. They should be forbidden to use any equipment unless the safe working-load is clearly visible.

All attached fittings (hooks, rings, etc.) should be as prescribed by the manufacturer. Hooks, shackles, and eyebolts should be equal to, or exceed, the safe working-load of the chain.

4.12.2 .2.2 Repairs

Modern chains are produced under closely controlled factory conditions using proper heat treatment and testing procedures. On-site repairs cannot provide the necessary controlled conditions to repair a damaged chain safely. Damaged chains must be returned to the manufacturer for repair or destroyed. In particular, watch for bent links, cranked welds and excessive wear.

4.12.2 .2.3 Logger chains

Logger chains or chains used to secure truck loads should not be used for rigging.

4.12.2.3. Wire Rope Slings

4.12.2.2.1 Wire Rope

Wire rope is the most common type of sling in use on construction sites. It is essential that each wire rope sling is properly constructed and used. All wire-rope slings should be manufactured, inspected, and load-tested by a recognized manufacturer.

4.12.2.2.2 Damaged Slings:

Damaged slings should be destroyed if there are:

* 10 random broken wires in one lay
* 4 broken wires in strands of a rope lay
* One broken wire at the fitting
* Severe localized abrasion or scraping
* Chinking, crushing, bridging, or any other damage causing distortion
* Evidence of heat damage
* End attachments are cracked, deformed, or excessively worn
* Bent or opened hooks
* Severe corrosion.

Each sling should bear a permanent manufacturer's identification stating the safe working-load (SWL) in tons and the serial number. Proof load-test and documentation of testing is required from the manufacturer.

4.12.2.4 Hooks

Hooks should be fitted with a safety catch on the hook opening, or should be housed with wire and a shackle or the hook should be designed so that the slings cannot be displaced.

Loads should be applied on the hook only in the part designed to take them. Point loading can result in over stressing the hook causing it to open or break. Therefore, point loading should not be permitted.

4.12.2.5 Shackles

Shackles (clevis) are used for making connections in rigging. They should be tested by the manufacturer and marked with the safe working load.

The pins are separate but matched parts of the shackles, so care must be taken to use the correct pin for each shackle. Re-bar, mild steel bolts or similar items are not acceptable replacements for shackle pins.

4.12.2.6 Rigger

The job of a rigger requires thorough training. The man assigned must be well acquainted with the capabilities of the crane being used, hand signals, the different functions of lifting gear, and the various methods of loading.

4.12.2.7 Overhead Power-Lines

There is an area surrounding every power-line that is referred to as the absolute limit of approach. It is strictly forbidden to move any crane boom or load-line or load into this area unless the line has been de-energized or insulated. There are no exceptions. The absolute limit of approach varies according to the following Table:

Table 3.2: Overhead Power-Lines Voltages & Their Limit of Approach

Line Voltage	Absolute Limit of Approach
Up to 250,000 volts	20 feet (6 meters)
Over 250,000	25 feet (7.5 meters)

It is recommended that the following checklist be used prior to any crane operation:

4.12.2.6 Pre-List Operation Checklist

- **OPERATOR**

- Current Saudi Arabia Government crane operator's license

OUTRIGGERS:

- Fully Extended
- Level Ground
- Compact Soil
- Heavy Pad Supports
- Locking Pins/Locks Set
- No Hydraulic Leaks
- No Damage
- Good Condition
- Wheels Off The Ground

- **OPERATION**

- Current Crane Safety Inspection Sticker
- Clear 360^0 Visibility
- No Shades/Curtains In Cab

- Load Charts In Cab
- Clear Visibility
- Wind, Above 20 mph (32 Km/h), No Go
- Do Not Operate During Storms And At Night
- Lightning, No Go
- Barricade Crane-Cab Swing Area
- Tag Lines In Use
- Clear Overhead Power Lines
- Clear Area Of Personnel 1-1/2 x Boom Lengths
- No Lifts Over Workers Or Critical Property
- Trial Lift, Float Load One Meter Off Ground To Check Balance
- Clear View Of Signal Man (Rigger)
- Do Not Pull Loads With Crane
- Load Radius Indicator
- Man Lift Work Permit
- Anti-Two Block Operational
- LMI (Load-Moment Indicator) Operational

·RIGGING

- Check All Rigging For Damage
- Check Sling-Load Capacity
- Check Block, Hooks, Etc. For Damage
- Hook Safety Latch In Place
- Record Weight Of Load
- Lift Plan Approved
- Use Load-Weight Measuring Device For Unknown Loads

- **TRAVELING**

- Block Secured
- Tires Properly Inflated And In Good Condition
- Brake Lights, Signals, Mirrors, Horn Operational
- Route Plan Checked For Firm Ground, Overhead And Side - Restrictions
- Escort Vehicles Required With Flashing Beacon Lights
- Speed To Be Maintained For Safe Limits (As Slow As Possible)

PARKING:

- Boom And Hook Block(s) Lowered To Travel Position
- Apply Swing Brake And Positive Swing Lock
- The Down Hook Block(s)
- Retract Stabilizers
- Retract Outriggers
- Extend Stabilizers And Latch Onto Float Pads
- Weight Of Chassis Off The Tires
- Let Engine Idle 3-5 Minutes
- Remove All Foreign Material From Cab(s)
- Close All Doors, Windows, Skylights And Compartments
- Turn Off Switches
- Stop Engine

4.13 AIR COMPRESSORS

Compressors are one of the most common pieces of equipment used in construction work. They can be used to supply air for portable power tools or to supply air to sustain men working with breathing apparatus in extremely hazardous atmospheres. There is a considerable difference in the quality of the air used for these two functions.

All employees on site must know the dangers of compressed air. Never use compressed air to dust off clothing or machinery. Horseplay with compressed air must be strictly forbidden. When compressed air is used in special cleaning/purging tasks, goggles and full face shield must be worn.

Compressors must be properly designed, inspected, tested and maintained. Relief valves should be installed and the air receiver must be periodically inspected.

Before start-up, a daily check should be made of the compressor's pressure-relief valve, fuel, oil and water-levels and the air reservoir should be drained of trapped water: The operating manual for the particular type of compressor used should be strictly followed.

When compressors supply air for breathing:

1. The air intake must be located so that it does not draw in exhaust gas

2. There must be a filter to remove oil mist

3. They must be equipped with an automatic high temperature alarm

4. The air must be tested periodically to be certain it is safe to breathe.

4.14 ELECTRICAL

4.14.1 General

The human senses (smell, taste, hearing, etc.) do not provide a warning of an electrical hazard. The great majority of electrical accidents result in burns. Fire and explosion from sparks in flammable atmospheres can and do lead to loss of life and serious damage to property. All electrical installations, no matter what voltages are used, should always be treated with great caution.

4.14.2 Temporary Installation

Distribution of electricity on a construction site is different from a permanent installation. As construction work proceeds, the type of equipment in use changes. From excavation to completion, there is a constant need for convenient means of connecting equipment. This requires a variety of voltages, phases, and current in different places at different times. Load requirements will vary considerably. All temporary electrical systems should conform to the National Electrical Code.

The contractor is responsible for the temporary electric supply system on a construction site and the safety measures associated with the National Electrical Code.

Cables on site are subject to rough treatment. Special care should be taken to ensure that the grounding conductor remains intact. If the conducting wire breaks, the supply will not be interrupted under a ground-fault condition and the system will no longer be safe.

Special care should be taken to ensure that the correct fuse or breaker ratings are strictly enforced and that the Ground-Fault Circuit Interrupters are installed properly on all circuits.

All installation work must be carried out by qualified, experienced electricians before connecting temporary electrical installations to existing installations.

A competent person must be made directly responsible for the overall safety of the installation. Its general usage, its maintenance, and any alterations and extensions to the system should be under his control. He must be at the site whenever work is being done. Before any part of a newly installed electrical system or its equipment is energized, it must be thoroughly tested. Safety can be ensured by regular inspection and maintenance.

4.14.3 Hand Tools and Lighting

Many injuries, fires, and explosions have resulted when extension lights with defective cords or fittings have been used or when bulbs have been broken, exposing the live filament wire to an explosive atmosphere. All electrically operated tools should be rated and used at a voltage not exceeding 125V. The use of 220V is prohibited.

Defective extension lights and electric hand tools should be repaired or replaced. A defective electrical tool or cord can cause burns, falls as a result of sudden shocks, or even fatalities.

Portable electric tools, extension lights and cords should be inspected each time they are issued and returned. This should be part of tool-store procedure. Frequent random checks should be made where these tools, lights and plugs are being used on site.

Portable hand lamps should comply with the following:

1. Metal shell, paper-lined lamp holders should not be used
2. Hand lamps should be equipped with an insulated handle
3. A substantial lamp-guard should be attached to the handle or holder. Metallic lamp-guards should be grounded. Three-wire power cords with grounding conductor should be used.

Failure of electrical equipment, because of misuse, is a frequent cause of shock. Workers are prone to abuse extension cords by pulling them over sharp metal objects, hanging them across equipment, kicking them, or letting them be run over by industrial equipment. They often strain the cords during use, causing the plug and fixture to part and expose live wires.

Many accidents occur when lower-volt equipment is plugged into higher-volt systems. Before any portable tool or extension light is plugged in, the voltage required for the tool or light must be the same as the power source, and the plugs must be checked for damage.

The importance of grounding all portable tools and lights cannot be emphasized too strongly. All non-current-carrying metal parts of any electrical equipment must be properly grounded. This will reduce the electrical shock hazard.

4.15 BLASTING

4.15.1 Abrasive Blast-Cleaning

This section covers blast-cleaning using abrasives in the form of sand, iron, shot, grit, slag or similar materials.

Operators of abrasive blast-cleaning equipment should have pre-placement physical examinations, including X-ray checks and pulmonary functions' tests, with repeat tests at least every two years.

The abrasive blast cleaning operator should wear an air-supplied protective hood approved (NIOSH/MSHA or equivalent) for the type of abrasive materials being used any other toxic contaminants (lead, zinc, etc.) that are present. Where blast-cleaning assistants could be exposed to silica sand dust or toxic contaminants, then self-contained or air-supplied breathing apparatus should be worn by the assistant.

A bonding system that bonds nozzle, hose, blasting equipment and the material being cleaned should be provided, and this bonding system should be grounded to prevent a build up of static charges. Ground continuity tests should be conducted periodically to ensure proper grounding.

4.15.2 Hydroblast and Steam-Cleaning

Hydroblast cleaning uses a high-pressure ambient temperature water-jet and steam-cleaning uses a high-pressure and high-temperature steam-jet. Extra caution should be exercised when using such equipment.

4.16 WELFARE FACILITIES

Adequate welfare facilities must be provided. The following are minimum requirements:

Canteens or eating areas adequate for the total work force must be provided. This area should be clean of refuse and meet Saudi Aramco Sanitary Code requirements.

A rest area must be provided.

Adequate toilet and washing facilities must be provided. Toilets should be provided in places where they may be easily accessible at the rate of one toilet for every fifteen workmen or less. These should be maintained in a sanitary condition.

An adequate supply of drinking water must be available. Common drinking cups or dips are prohibited.

First-aid facilities must be supplied and arrangements made for medical care and for emergency situations.

Where necessary, safe smoking areas must be provided.

4.17 HEAVY EQUIPMENT

1.17.1 General Requirements

Before any mechanical equipment is used in a Saudi Aramco restricted area, all required work permits must be obtained.

All machinery should be inspected before being placed in service and at regular intervals thereafter.

Maintenance schedules should be established for each piece of equipment and strictly followed.

No repair, adjustment, or replacement of parts on moving machinery is permitted. Before any repairs, all equipment must be stopped and deactivated so that it cannot be unintentionally started.

At the start of each shift, the operator must check oil, water, fuel, and hydraulic levels. He must also check that all gauges are operating and that the machine is functioning smoothly. Safety equipment (e.g. guards, limit switches, governors) must be checked daily.

Equipment traveling or working on the highway must have lights and reflectors. Equipment should be parked clear of the roadway. If this is not possible, flashing lights, cones, or other warning devices should be used to alert approaching traffic.

When vehicles are left unattended (even overnight) engines must be stopped, oaring brakes applied and the wheels chocked. Blades, scraper bowls, and other hydraulic equipment must be lowered to the ground before the operator leaves the machine. The ignition key should be removed and/or battery cables disconnected to avoid start-up by unauthorized personnel.

Unless otherwise instructed, operators must dismount from machines while maintenance or repair work is being carried out.

Cabs fitted to equipment must give 360° visibility. Cabs must be kept clean and clear of such items as rubbish and loose tools. Windows must be clean at all times and should be replaced if the glass becomes pitted, racked or broken.

Where the operator of a mobile machine cannot see the area around his machine, an attendant must be in a position to direct and assist the operator.

All equipment must be located so that exhaust fumes will not affect workers in the area. Gasoline-driven equipment should not be used inside a building or other confined space.

4.17.2 Dumpers and Dump Trucks

Dumpers and dump trucks, commonly used for construction work, often travel on the public highway. Therefore, it is essential they be properly maintained.

The latch on dumper skips must be in good working order, and the release mechanism should function smoothly.

Dumpers are not designed to carry passengers. It must be strictly forbidden for employees to ride in the skip or on the engine cover.

When repairs or maintenance are being carried out on a hydraulically operated dump truck, the dump body should be fully lowered.

Booms on excavators must be latched before travel.

Excavation should not take place closer than 3 meters to the nearest pipeline or other equipment in place.

4.17.3 Fork-Lift Trucks

Fork-lift trucks are designed to operate on firm, level ground. This type of equipment has a limited use in construction operations. They are, however, sometimes used in materials' handling yards and for placing loads where there are firm ground conditions. Operators of fork-lift trucks must have a valid Saudi Arabia Government heavy-equipment license.

It is essential that drivers be fully trained and experienced. They must be able to manipulate loads smoothly and efficiently.

A specific course of instruction should be established for fork-lift drivers. They should not be allowed to use the vehicles on site until they have taken the course.

Special equipment fitted to the truck, in addition to, or in place of the forks, must be designed for the specific machine.

The truck should be equipped with overhead protection.

When traveling with a load on the forks, the forks should be as low as possible to maintain stability.

If the load being carried obstructs the operator's forward view, he should travel in reverse.

4.17.4 Graders, Dozers, Scrapers, Loaders and Miniloaders

Heavy earth-moving equipment only allows the operator a limited view of the immediate area. It is therefore, essential that a banksman be appointed to warn the operator of hazards that cannot be seen from the operator's position.

This equipment should be equipped with rollover protection. A valid Saudi Arab Government heavy-equipment license is required.

Before moving his machine, the driver must walk around it to see that the area is clear.

Men must not be allowed to sit or lie in the area around the machine.

The engine should not be left running when the driver is not at the controls. Before leaving his machine, a driver must shut off the engine and remove the ignition key.

Blades, scraper bowls, etc. must be lowered to the ground before the driver leaves his unit. The wheels should be properly chocked.

If there is work to be done underneath such hydraulic equipment, the equipment must be blocked in position.

4.18. CHEMICALS

4.18.1 General

As a general precaution, rough handling and shock should be avoided. Chemicals should not be allowed to mix with other chemicals unless it is known that no harmful reaction will occur.

4.18.2. Transportation

During transportation, hazardous materials must be protected against shock, accidental mixing with other materials, damage to containers, undue heat from the sun or other sources, and theft, which could allow the hazardous materials to come into contact with people who are unaware of the dangers.

4.18.3 Storage

The NFPA fire codes contain recommendations for safe storage of flammable liquids, compressed gases, and typical combustible or explosive solids. Precautions must be taken to avoid shock, and undue or unplanned mixing. There are some cases where separating walls or specified distances are required.

4.18.4 Containers

Hazardous materials must be stored in containers that are safe for the transportation and use of the material. Containers must be labeled with the appropriate hazardous materials' label to indicate the actual contents. All safety factors must be observed when transferring materials.

CHAPTER 5

CALCULATIONS AND DATA ANALYSIS

5.1 ACCIDENT RATE (AR)

The following formula was used to calculate the accident rate. The recorded injuries in this research include the following:

Lost-Day Cases: Injuries that put a worker off the job for some time.

Doctor Cases: Injuries that require professional and medical attention but the employee can go back to work immediately after treatment.

Accident Rate $= \dfrac{\text{Number of recorded injuries} \times 200{,}000}{\text{Number of employee exposure hours}}$

Av. No. of employees on site $= N$,

Employee's exposure hours $= Z$

Employees' exposure hours $= N \times Z = Y$,

Recorded injuries $= M$

Accident rate $= \dfrac{M \times 200{,}000}{Y}$

Each of the multiple-choice questions had five expected answers and each of these answers had been assigned a given value:

Always	= 25
Frequently	= 20
Sometimes	= 15
Rarely	= 10
Never	= 5

The data collected for a particular question gathered from the projects was measured against the accident rates of projects. Then the process was repeated for all the forty-five projects. The results are presented in a tabular form.

Then the Pearson correlation-coefficient (r) is used to find out how individual differences in response to that particular question were related to individual differences in accident rates.

5.2 PEARSON R:

The correlation-coefficient is a measure of linear correlation which indicates both the direction and the strength of the relation between two variables in a single number. The sign of the coefficient (+ or -) indicates whether the type of relation is positive or negative. If the relation between two variables is a high-high or low-low pairing, then the relation is called positive. However, if the relation between the two variables has a reverse pairing (high with low, low with high), then the relation is called negative.

The numerical value of the coefficient indicates the strength of the relation. When the relation between the two variables is perfect, the numerical value is 1.0, whereas the numerical value is 0.0 when there is no systematic relation existing between the two variables. Therefore, the typical range of values for the Pearson coefficient extends from + 1.0 for a perfect positive relation, through 0.0 for no systematic relation to - 1.0 for a perfect negative relation.

The basic formula for the Pearson correlation-coefficient (r) between two variables such as (X,Y) is:

$$r = \frac{\sum Zx\,Zy}{N}$$

$$Zx = \frac{X-Mx}{\sigma x}$$

$$Zy = \frac{Y-My}{\sigma y}$$

$$\sigma x = \frac{(X-Mx)^2}{N}$$

$$\sigma y = \frac{(Y-My)^2}{N}$$

Mx = The average of values of x

N = Number of items (Project)

X = Variable Value (in this case accident rate)

Y	=	Variable value (such as safety level, safety officer, job schedule, planning meetings, safety meetings, safety accountability, experienced workers, and training new workers.
Z	=	The value that indicates how many standard deviations the score lies above (or below) the mean score.
Zx	=	The value of z in the x distribution
Zy	=	The value of z in the y distribution
My	=	The average of values of y
σx	=	The standard deviation of value of x
σy	=	The standard deviation of values of y

As stated in the formula above, the r value depends on the Z scores. The Z score for any score indicates the location of that score in a distribution of scores. It shows precisely how a score deviates from the mean score.

The correlation-coefficients in this report are calculated for data in which each case has two scores. One is the accident rate (AR) which is labeled as (X) and the other one is the safety level or a particular question response (Q #) which is labeled (Y).

Since there are two scores (AR and question response) for each project, then there are two Z scores for each project.

In order to compute the value of person r we need to calculate each Z score for AR (X), for the safety level and for each question response (Y). To achieve this we need to compute the mean and the standard deviation for accident rate(Mx, x) and for each question response (My, y).

5.3 The Correlation between Accident Rate & Safety Level

In Tables 5.1-5.4 the accident-rate value for each project is presented in the third column and its mean is calculated in the last row, (third column) space. The accident-rate (AR) deviation from the mean for each project is calculated in column three. Then the accident-rate mean value is squared in column four and it is totaled in the second row from the bottom of the table.

The standard deviation for the accident rate and for each question response is presented in columns nine and ten respectively. The Z values for each accident rate and each question's response are calculated in columns eleven and twelve respectively.

The thirteenth column in each table contains the product of the two Z scores for each product. The sum of this product is also calculated at the second row from the bottom of the table. The sum of these products is divided by the number of projects (N=45) to get the value or r, which is presented in the last column of each table.

Similarly in Tables 5.5- 5.11, the response values for a question are presented in the fifth column and the mean is calculated in the last row, (fifth column) space. The deviation for each response from the mean is calculated in column six and squared in column seven. The total of the squared values is presented at the end of the seventh column.

The standard deviation for the accident rate and for each question response is presented in columns ten and eleven respectively. The Z values for each accident rate and each question's response are calculated in columns twelve and thirteen respectively.

The fourteenth column in each table contains the product of the two z scores for each product. The sum of this product is also calculated at the second row from the bottom of the table. The sum of these products is divided by the number of projects (n=45) to get the value or r, which is presented in the last column of each table

The calculation for the Pearson (r) correlation-coefficient between accident rate (AR) and the measured safety level in all forty-five projects is carried out and shown in the next Table 5.1. The resulting coefficient value is r= -0.95. The calculation showed that, as the safety level increases in a project, the accident rate (AR) decreases. This inverse relation is represented by the negative sign in the value of r. Furthermore, the strength of the correlation between the safety level and the accident rate is represented in the value of r , which is 0.95. This value is very close to the maximum value of 1.0 for perfect correlation.

TABLE-5.1: CORRELATION BETWEEN SAFETY LEVEL AND ACCIDENT RATE FOR ALL TYPE OF PROJECTS

Prj.	Size	AR (X)	SL (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
1	S	43.00	48.54	14.95	223.48	-23.23	539.56	18.70	17.49	0.80	-1.33	-1.06	-0.95
2	S	28.00	78.80	-0.05	0.00	7.03	49.44	18.70	17.49	0.00	0.40	0.00	
3	S	51.00	53.46	22.95	526.67	-18.31	335.20	18.70	17.49	1.23	-1.05	-1.28	
4	S	38.60	64.85	10.55	111.29	-6.92	47.86	18.70	17.49	0.56	-0.40	-0.22	
5	S	21.70	85.84	-6.35	40.33	14.07	198.01	18.70	17.49	-0.34	0.80	-0.27	
6	S	75.76	41.97	47.71	2276.18	-29.80	887.95	18.70	17.49	2.55	-1.70	-4.35	
7	S	30.32	72.95	2.27	5.15	1.18	1.40	18.70	17.49	0.12	0.07	0.01	
8	S	32.64	66.16	4.59	21.06	-5.61	31.45	18.70	17.49	0.25	-0.32	-0.08	
9	S	44.40	62.73	16.35	267.30	-9.04	81.69	18.70	17.49	0.87	-0.52	-0.45	
10	S	38.30	64.68	10.25	105.05	-7.09	50.25	18.70	17.49	0.55	-0.41	-0.22	
11	S	15.25	84.33	-12.80	163.86	12.56	157.79	18.70	17.49	-0.68	0.72	-0.49	
12	S	15.43	84.51	-12.62	159.28	12.74	162.35	18.70	17.49	-0.67	0.73	-0.49	
13	S	50.50	48.61	22.45	503.97	-23.16	536.31	18.70	17.49	1.20	-1.32	-1.59	
14	S	11.48	89.02	-16.57	274.59	17.25	297.62	18.70	17.49	-0.89	0.99	-0.87	
15	S	57.61	43.68	29.56	873.75	-28.09	788.96	18.70	17.49	1.58	-1.61	-2.54	
16	S	48.71	46.01	20.66	426.81	-25.76	663.50	18.70	17.49	1.10	-1.47	-1.63	
17	S	4.41	91.62	-23.64	558.88	19.85	394.08	18.70	17.49	-1.26	1.14	-1.44	
18	S	55.56	51.49	27.51	756.76	-20.28	411.22	18.70	17.49	1.47	-1.16	-1.71	
19	S	49.00	46.43	20.95	438.87	-25.34	642.04	18.70	17.49	1.12	-1.45	-1.62	
20	S	3.90	97.00	-24.15	583.25	25.23	636.63	18.70	17.49	-1.29	1.44	-1.86	
21	M	53.00	47.86	24.95	622.47	-23.91	571.61	18.70	17.49	1.33	-1.37	-1.82	
22	M	50.00	55.19	21.95	481.77	-16.58	274.84	18.70	17.49	1.17	-0.95	-1.11	
23	M	27.16	75.18	-0.89	0.79	3.41	11.64	18.70	17.49	-0.05	0.20	-0.01	
24	M	18.37	72.18	-9.68	93.72	0.41	0.17	18.70	17.49	-0.52	0.02	-0.01	
25	M	44.64	58.19	16.59	275.21	-13.58	184.37	18.70	17.49	0.89	-0.78	-0.69	
26	M	45.00	57.91	16.95	287.28	-13.86	192.06	18.70	17.49	0.91	-0.79	-0.72	
27	M	43.16	49.34	15.11	228.29	-22.43	503.04	18.70	17.49	0.81	-1.28	-1.04	
28	M	23.10	83.41	-4.95	24.51	11.64	135.53	18.70	17.49	-0.26	0.67	-0.18	
29	M	28.00	62.24	-0.05	0.00	-9.53	90.79	18.70	17.49	0.00	-0.54	0.00	
30	M	35.00	63.54	6.95	48.29	-8.23	67.71	18.70	17.49	0.37	-0.47	-0.17	
31	M	38.60	50.01	10.55	111.29	-21.76	473.43	18.70	17.49	0.56	-1.24	-0.70	
32	M	5.98	90.61	-22.07	487.11	18.84	355.00	18.70	17.49	-1.18	1.08	-1.27	
33	M	11.97	84.37	-16.08	258.59	12.60	158.80	18.70	17.49	-0.86	0.72	-0.62	
34	M	8.91	89.22	-19.14	366.37	17.45	304.56	18.70	17.49	-1.02	1.00	-1.02	
35	M	13.23	81.45	-14.82	219.65	9.68	93.73	18.70	17.49	-0.79	0.55	-0.44	
36	L	3.80	95.21	-24.25	588.09	23.44	549.51	18.70	17.49	-1.30	1.34	-1.74	
37	L	14.00	78.06	-14.05	197.42	6.29	39.58	18.70	17.49	-0.75	0.36	-0.27	
38	L	3.96	88.84	-24.09	580.36	17.07	291.44	18.70	17.49	-1.29	0.98	-1.26	
49	L	11.55	88.00	-16.50	272.27	16.23	263.46	18.70	17.49	-0.88	0.93	-0.82	
40	L	26.70	75.32	-1.35	1.82	3.55	12.61	18.70	17.49	-0.07	0.20	-0.01	
41	L	2.52	95.71	-25.53	651.81	23.94	573.20	18.70	17.49	-1.37	1.37	-1.87	
42	L	11.60	94.41	-16.45	270.62	22.64	512.64	18.70	17.49	-0.88	1.29	-1.14	
43	L	1.40	96.51	-26.65	710.26	24.74	612.14	18.70	17.49	-1.43	1.41	-2.02	
44	L	3.70	94.57	-24.35	592.95	22.80	519.91	18.70	17.49	-1.30	1.30	-1.70	
45	L	21.36	79.57	-6.69	44.77	7.80	60.86	18.70	17.49	-0.36	0.45	-0.16	
TOT.					15732.3		13766.0					-42.96	
AVG.		28.05	71.77										

SL=Safety level　AR=accident rate　Mx=Mean value of X　σX= Standard deviation of X　S = Small

(X-Mx)2 = Square of value X minus its mean　r = Correlation between the values of X and Y　M = Medium　L= Large

The correlation between the safety level and accident rate in small projects is presented in Table 5.2. The average accident rate (AR) and the average safety level (SL) are 35.78 and 66.28 respectively, which is higher than both averages for all projects; refer to Table 5.1. This shows that small projects are less safe than the rest of the group.

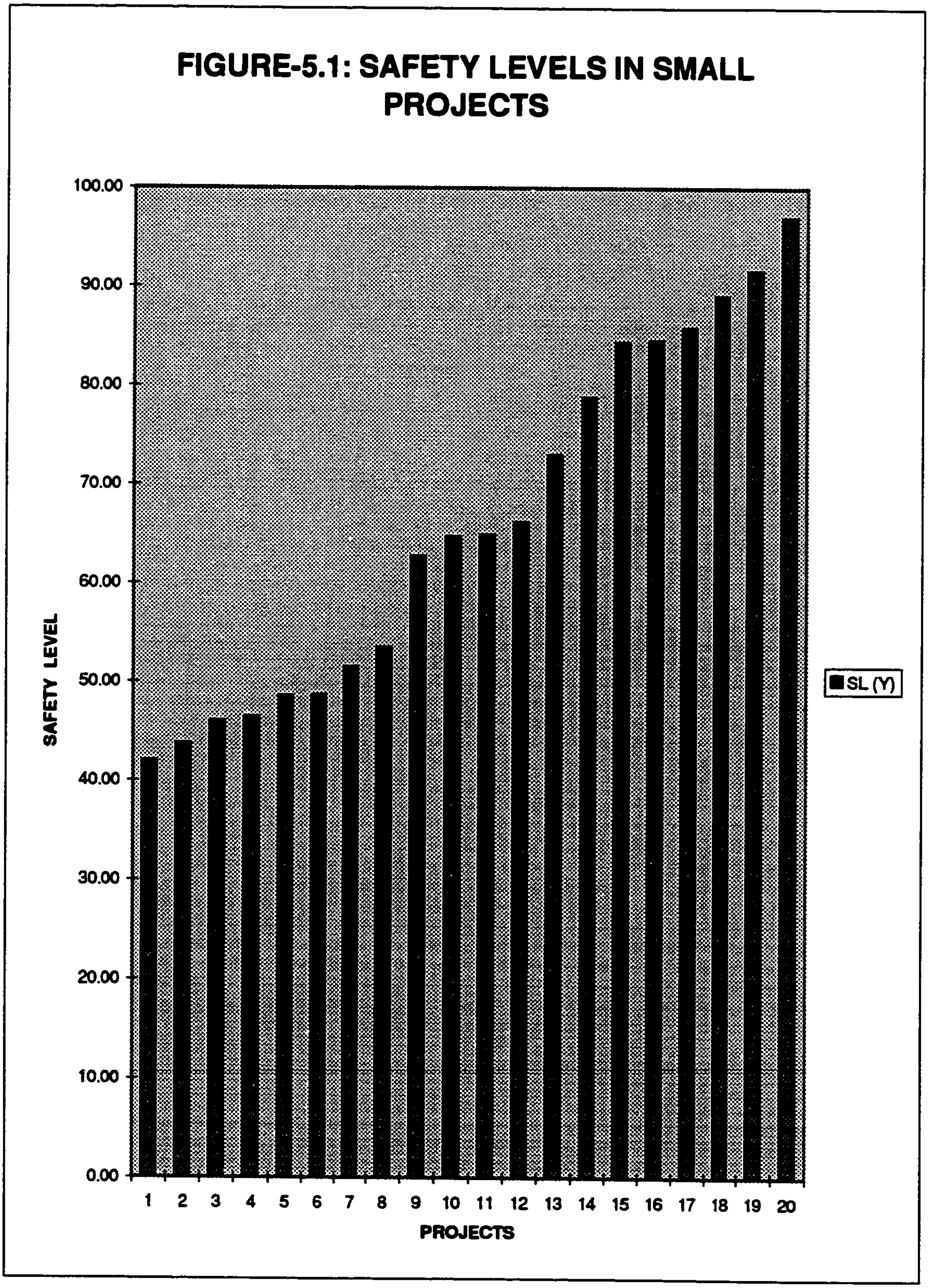
TABLE-5.2 : CORRELATION BETWEEN SAFETY LEVEL AND ACCIDENT RATE IN SMALL PROJECTS

Prj.	Size	AR (X)	SL (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σx	σy	Zx	Zy	ZxZy	r
1	S	43.00	41.97	7.22	52.15	-24.16	583.90	18.87	17.72	0.38	-1.36	-0.52	-0.16
2	S	28.00	43.68	-7.78	60.51	-22.45	504.18	18.87	17.72	-0.41	-1.27	0.52	
3	S	51.00	46.01	15.22	231.69	-20.12	404.98	18.87	17.72	0.81	-1.14	-0.92	
4	S	38.60	46.43	2.82	7.96	-19.70	388.25	18.87	17.72	0.15	-1.11	-0.17	
5	S	21.70	48.54	-14.08	198.20	-17.59	309.55	18.87	17.72	-0.75	-0.99	0.74	
6	S	75.76	48.61	39.98	1598.52	-17.52	307.09	18.87	17.72	2.12	-0.99	-2.10	
7	S	30.32	51.49	-5.46	29.80	-14.64	214.45	18.87	17.72	-0.29	-0.83	0.24	
8	S	32.64	53.46	-3.14	9.85	-12.67	160.63	18.87	17.72	-0.17	-0.72	0.12	
9	S	44.40	62.73	8.62	74.33	-3.40	11.59	18.87	17.72	0.46	-0.19	-0.09	
10	S	38.30	64.68	2.52	6.36	-1.45	2.11	18.87	17.72	0.13	-0.08	-0.01	
11	S	15.25	64.85	-20.53	421.42	-1.28	1.65	18.87	17.72	-1.09	-0.07	0.08	
12	S	15.43	66.16	-20.35	414.06	0.03	0.00	18.87	17.72	-1.08	0.00	0.00	
13	S	50.50	72.95	14.72	216.72	6.82	46.46	18.87	17.72	0.78	0.38	0.30	
14	S	11.48	78.80	-24.30	590.42	12.67	160.43	18.87	17.72	-1.29	0.71	-0.92	
15	S	57.61	84.33	21.83	476.61	18.20	331.09	18.87	17.72	1.16	1.03	1.19	
16	S	48.71	84.51	12.93	167.22	18.38	337.68	18.87	17.72	0.69	1.04	0.71	
17	S	4.41	85.84	-31.37	983.98	19.71	388.33	18.87	17.72	-1.66	1.11	-1.85	
18	S	55.56	89.02	19.78	391.31	22.89	523.77	18.87	17.72	1.05	1.29	1.35	
19	S	49.00	91.62	13.22	174.81	25.49	649.54	18.87	17.72	0.70	1.44	1.01	
20	S	3.90	97.00	-31.88	1016.24	30.87	952.71	18.87	17.72	-1.69	1.74	-2.94	
TOT.					7122.2		6278.4					-3.25	
AVG.		35.78	66.13										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

The safety level in small projects fluctuates between 42 and 99 (see the graph 5.3). However, the average safety level is approximately 66, which is less than the average for all projects.



The correlation computation between the safety level and accident rate in medium and large projects is shown in Tables 5.3 and 5.4 respectively. The average safety level in medium projects is slightly lower than the average for all projects, while the average safety level is higher for large projects.

TABLE- 5.3 : CORRELATION BETWEEN SAFETY LEVEL AND ACCIDENT RATE IN MEDIUM PROJECTS

Prj.	Size	AR (X)	SL (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
21	M	53.00	47.86	23.26	540.97	-20.19	407.50	15.19	14.63	1.53	-1.38	-2.11	-0.70
22	M	50.00	49.34	20.26	410.41	-18.71	349.94	15.19	14.63	1.33	-1.28	-1.71	
23	M	27.16	50.01	-2.58	6.66	-18.04	325.32	15.19	14.63	-0.17	-1.23	0.21	
24	M	18.37	55.19	-11.37	129.31	-12.86	165.29	15.19	14.63	-0.75	-0.88	0.66	
25	M	44.64	57.91	14.90	221.97	-10.14	102.75	15.19	14.63	0.98	-0.69	-0.68	
26	M	45.00	58.19	15.26	232.83	-9.86	97.15	15.19	14.63	1.00	-0.67	-0.68	
27	M	43.16	62.24	13.42	180.06	-5.81	33.72	15.19	14.63	0.88	-0.40	-0.35	
28	M	23.10	63.54	-6.64	44.11	-4.51	20.31	15.19	14.63	-0.44	-0.31	0.13	
29	M	28.00	72.18	-1.74	3.03	4.13	17.08	15.19	14.63	-0.11	0.28	-0.03	
30	M	35.00	75.18	5.26	27.65	7.13	50.88	15.19	14.63	0.35	0.49	0.17	
31	M	38.60	81.45	8.86	78.48	13.40	179.65	15.19	14.63	0.58	0.92	0.53	
32	M	5.98	83.41	-23.76	564.60	15.36	236.03	15.19	14.63	-1.56	1.05	-1.64	
33	M	11.97	84.37	-17.77	315.82	16.32	266.45	15.19	14.63	-1.17	1.12	-1.31	
34	M	8.91	89.22	-20.83	433.94	21.17	448.31	15.19	14.63	-1.37	1.45	-1.98	
35	M	13.23	90.61	-16.51	272.62	22.56	509.10	15.19	14.63	-1.09	1.54	-1.68	
TOT.					3462.5		3209.5					-10.46	
AVG.		29.74	68.05										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

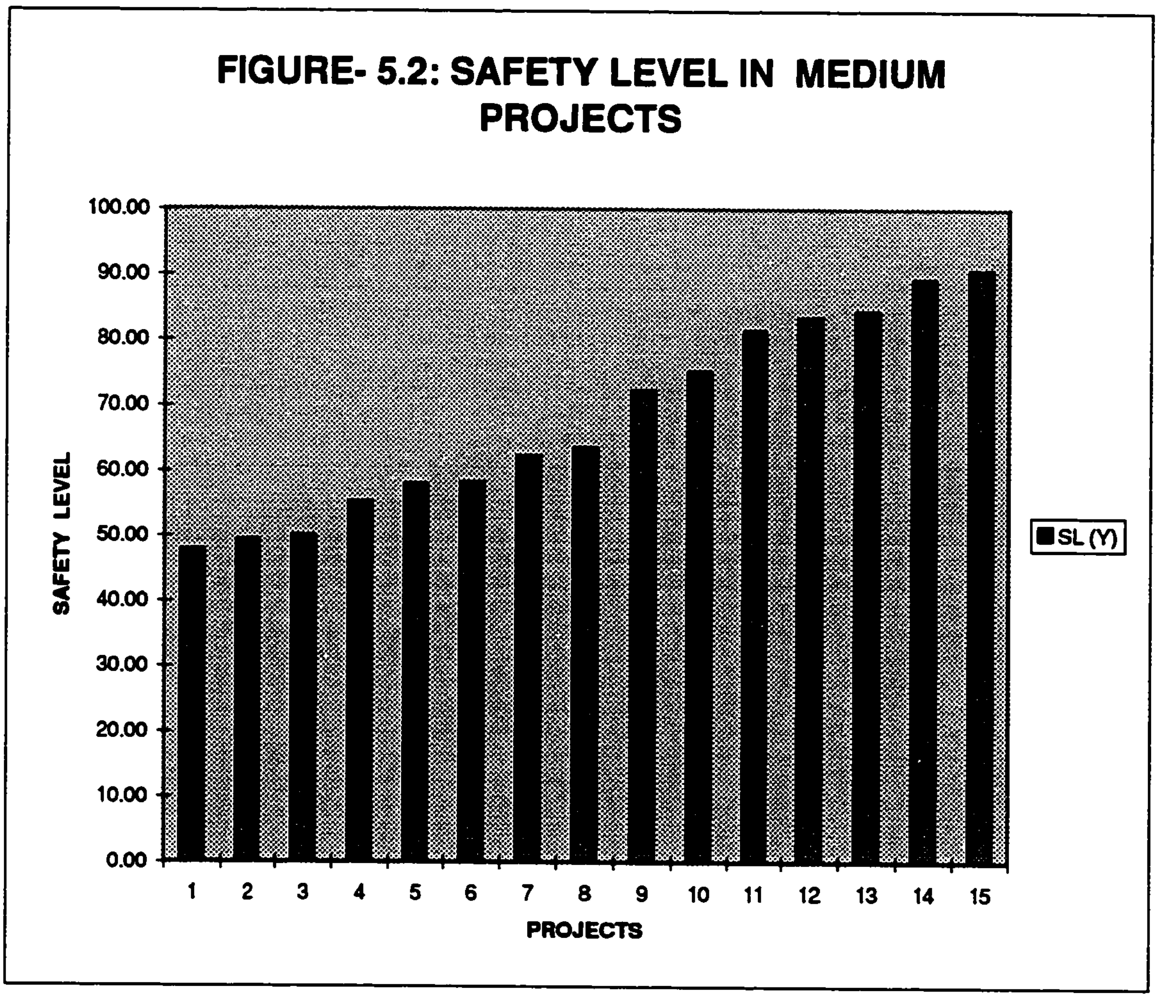
TABLE- 5.4 : CORRELATION BETWEEN SAFETY LEVEL AND ACCIDENT RATE IN LARGE PROJECTS

Prj.	Size	AR (X)	SL (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
36	L	26.70	75.32	16.64	276.92	-13.30	176.89	8.21	7.72	2.03	-1.72	-3.49	-0.88
37	L	14.00	78.06	3.94	15.53	-10.56	111.51	8.21	7.72	0.48	-1.37	-0.66	
38	L	21.36	79.57	11.30	127.71	-9.05	81.90	8.21	7.72	1.38	-1.17	-1.61	
40	L	11.55	88.00	1.49	2.22	-0.62	0.38	8.21	7.72	0.18	-0.08	-0.01	
41	L	3.96	88.84	-6.10	37.20	0.22	0.05	8.21	7.72	-0.74	0.03	-0.02	
42	L	11.60	94.41	1.54	2.37	5.79	33.52	8.21	7.72	0.19	0.75	0.14	
43	L	3.70	94.57	-6.36	40.44	5.95	35.40	8.21	7.72	-0.77	0.77	-0.60	
44	L	3.80	95.21	-6.26	39.18	6.59	43.43	8.21	7.72	-0.76	0.85	-0.65	
45	L	2.52	95.71	-7.54	56.84	7.09	50.27	8.21	7.72	-0.92	0.92	-0.84	
49	L	1.40	96.51	-8.66	74.98	7.89	62.25	8.21	7.72	-1.06	1.02	-1.08	
TOT.					673.4		595.6					-8.83	
AVG.		10.06	88.62										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

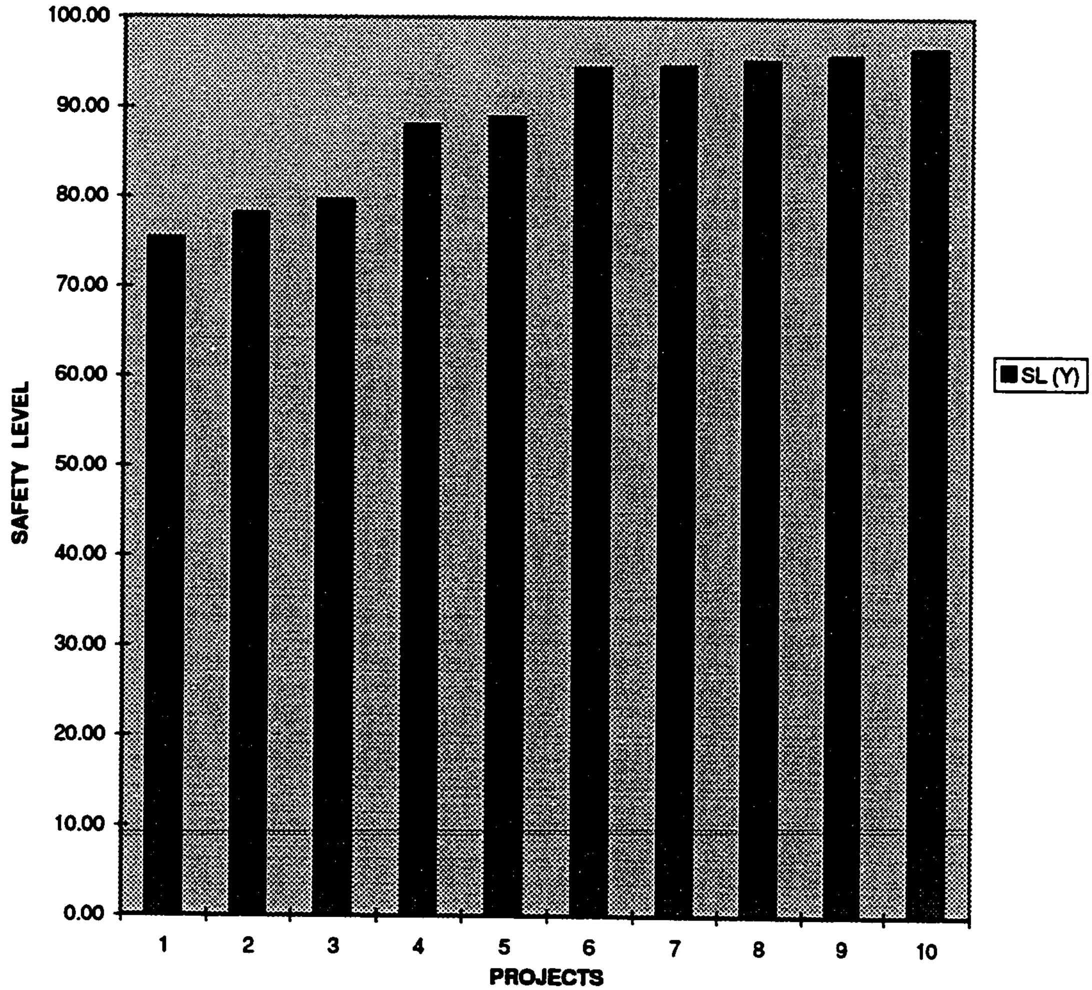
(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

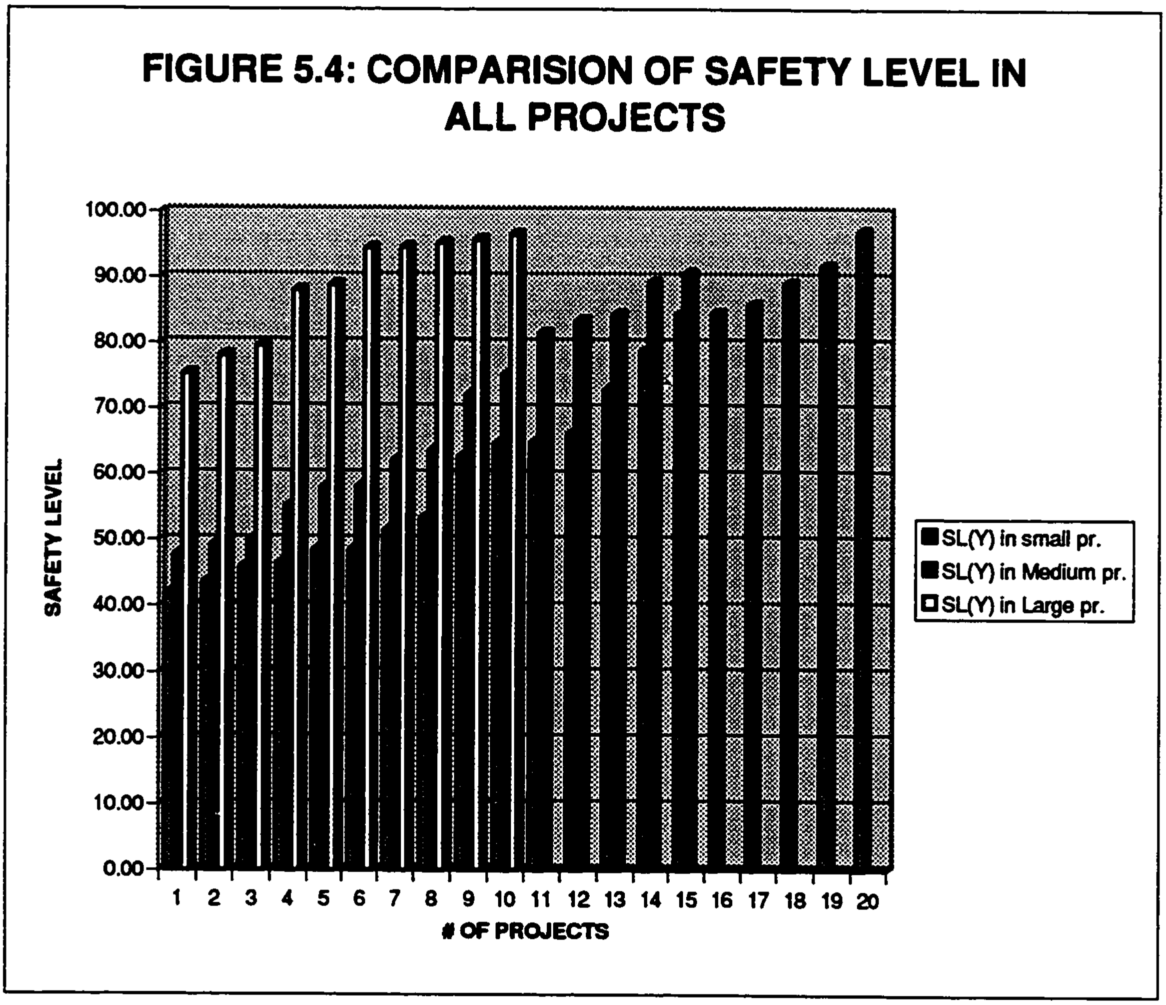
The figure below shows the safety level in medium projects, which ranges between 49 and 90, with an average of 68.



The next figure shows the safety level in large projects, which ranges between 78 and 96.5, with an average of 88.6.

FIGURE -5.3: SAFETY LEVELS IN LARGE PROJECTS





The figure above shows the combined safety levels for small, medium and large projects.

5.4 MIDDLE MANAGEMENT INVOLVEMENT

5.4.1 Relationship betweenSafety Officer and Accident Rate.

To assess the effect of an assigned safety officer on the project, the following question was asked:

(Q. # 5) Do you have a full-time safety officer assigned to the project?

Table 5.5: Project Responses to the Question of an Assigned Safety Officer

Response	No. of Projects (N)	Average safety level (SL)	Average accident rate(AR)
Always	10	93	5
Frequently	9	81	17
Sometimes	8	78	25
Rarely	5	61	40
Never	13	50	51

The results clearly show that projects that have assigned safety officers have a high safety level and a low accident rate. The correlation between safety officer and the accident rate resulted in a value of r = (-0.94); refer to Table 5.6. The negative sign represents the inverse relation between the assigned safety officer and the accident rate, while the magnitude of the r value represents the strength of the correlation, which has a maximum value of one. Some projects share the safety officer with other projects within the same Company. However, the more time the safety officer spends on a project, the safer that project becomes.

TABLE- 5.6 : THE CORRELATION BETWEEN ASSIGNED SAFETY OFFICER AND ACCIDENT RATE

Prj.	Size	SL	AR (X)	Q # 5 (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
1	S	48.54	43.00	10	14.95	223.48	-4.78	22.83	18.70	7.67	0.80	-0.62	-0.50	-0.94
2	S	78.80	28.00	15	-0.05	0.00	0.22	0.05	18.70	7.67	0.00	0.03	0.00	
3	S	53.46	51.00	5	22.95	526.67	-9.78	95.60	18.70	7.67	1.23	-1.27	-1.56	
4	S	64.85	38.60	10	10.55	111.29	-4.78	22.83	18.70	7.67	0.56	-0.62	-0.35	
5	S	85.84	21.70	20	-6.35	40.33	5.22	27.27	18.70	7.67	-0.34	0.68	-0.23	
6	S	41.97	75.76	5	47.71	2276.18	-9.78	95.60	18.70	7.67	2.55	-1.27	-3.25	
7	S	72.95	30.32	15	2.27	5.15	0.22	0.05	18.70	7.67	0.12	0.03	0.00	
8	S	66.16	32.64	20	4.59	21.06	5.22	27.27	18.70	7.67	0.25	0.68	0.17	
9	S	62.73	44.40	10	16.35	267.30	-4.78	22.83	18.70	7.67	0.87	-0.62	-0.54	
10	S	64.68	38.30	10	10.25	105.05	-4.78	22.83	18.70	7.67	0.55	-0.62	-0.34	
11	S	84.33	15.25	20	-12.80	163.86	5.22	27.27	18.70	7.67	-0.68	0.68	-0.47	
12	S	84.51	15.43	20	-12.62	159.28	5.22	27.27	18.70	7.67	-0.67	0.68	-0.46	
13	S	48.61	50.50	5	22.45	503.97	-9.78	95.60	18.70	7.67	1.20	-1.27	-1.53	
14	S	89.02	11.48	20	-16.57	274.59	5.22	27.27	18.70	7.67	-0.89	0.68	-0.60	
15	S	43.68	57.61	5	29.56	873.75	-9.78	95.60	18.70	7.67	1.58	-1.27	-2.02	
16	S	46.01	48.71	5	20.66	426.81	-9.78	95.60	18.70	7.67	1.10	-1.27	-1.41	
17	S	91.62	4.41	25	-23.64	558.88	10.22	104.49	18.70	7.67	-1.26	1.33	-1.68	
18	S	51.49	55.56	5	27.51	756.76	-9.78	95.60	18.70	7.67	1.47	-1.27	-1.88	
19	S	46.43	49.00	5	20.95	438.87	-9.78	95.60	18.70	7.67	1.12	-1.27	-1.43	
20	S	97.00	3.90	25	-24.15	583.25	10.22	104.49	18.70	7.67	-1.29	1.33	-1.72	
21	M	47.86	53.00	5	24.95	622.47	-9.78	95.60	18.70	7.67	1.33	-1.27	-1.70	
22	M	55.19	50.00	5	21.95	481.77	-9.78	95.60	18.70	7.67	1.17	-1.27	-1.50	
23	M	75.18	27.16	15	-0.89	0.79	0.22	0.05	18.70	7.67	-0.05	0.03	0.00	
24	M	72.18	18.37	20	-9.68	93.72	5.22	27.27	18.70	7.67	-0.52	0.68	-0.35	
25	M	58.19	44.64	5	16.59	275.21	-9.78	95.60	18.70	7.67	0.89	-1.27	-1.13	
26	M	57.91	45.00	5	16.95	287.28	-9.78	95.60	18.70	7.67	0.91	-1.27	-1.16	
27	M	49.34	43.16	5	15.11	228.29	-9.78	95.60	18.70	7.67	0.81	-1.27	-1.03	
28	M	83.41	23.10	15	-4.95	24.51	0.22	0.05	18.70	7.67	-0.26	0.03	-0.01	
29	M	62.24	28.00	15	-0.05	0.00	0.22	0.05	18.70	7.67	0.00	0.03	0.00	
30	M	63.54	35.00	10	6.95	48.29	-4.78	22.83	18.70	7.67	0.37	-0.62	-0.23	
31	M	50.01	38.60	5	10.55	111.29	-9.78	95.60	18.70	7.67	0.56	-1.27	-0.72	
32	M	90.61	5.98	25	-22.07	487.11	10.22	104.49	18.70	7.67	-1.18	1.33	-1.57	
33	M	84.37	11.97	20	-16.08	258.59	5.22	27.27	18.70	7.67	-0.86	0.68	-0.59	
34	M	89.22	8.91	25	-19.14	366.37	10.22	104.49	18.70	7.67	-1.02	1.33	-1.36	
35	M	81.45	13.23	20	-14.82	219.65	5.22	27.27	18.70	7.67	-0.79	0.68	-0.54	
36	L	95.21	3.80	25	-24.25	588.09	10.22	104.49	18.70	7.67	-1.30	1.33	-1.73	
37	L	78.06	14.00	20	-14.05	197.42	5.22	27.27	18.70	7.67	-0.75	0.68	-0.51	
38	L	88.84	3.96	25	-24.09	580.36	10.22	104.49	18.70	7.67	-1.29	1.33	-1.72	
49	L	88.00	11.55	25	-16.50	272.27	10.22	104.49	18.70	7.67	-0.88	1.33	-1.18	
40	L	75.32	26.70	15	-1.35	1.82	0.22	0.05	18.70	7.67	-0.07	0.03	0.00	
41	L	95.71	2.52	25	-25.53	651.81	10.22	104.49	18.70	7.67	-1.37	1.33	-1.82	
42	L	94.41	11.60	15	-16.45	270.62	0.22	0.05	18.70	7.67	-0.88	0.03	-0.03	
43	L	96.51	1.40	25	-26.65	710.26	10.22	104.49	18.70	7.67	-1.43	1.33	-1.90	
44	L	94.57	3.70	25	-24.35	592.95	10.22	104.49	18.70	7.67	-1.30	1.33	-1.74	
45	L	79.57	21.36	15	-6.69	44.77	0.22	0.05	18.70	7.67	-0.36	0.03	-0.01	
TOT.						15732.3		2647.8					-42.3	
AVG.		71.77	28.05	14.78										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

Q # 5 (Y) = Responses to question number 5 (Always=25, Frequently = 20, Sometimes=15, Rarely= 10, Never = 5)

5.4.2 Relationship between Job Schedule and Accident Rate.

The job schedule is one of the important factors that could affect productivity and, to a great degree, safety. Therefore, the following question was asked:

(Q # 6) Is there a job schedule ?

Table 5.7: Project Responses to the Question of Job Schedule.

Response	No. of Projects (N)	Average safety level (SL)	Average accident rate(AR)
Always	16	88	9
Frequently	9	82	21
Sometimes	6	62	38
Rarely	8	52	47
Never	6	49	53

The results indicate that out of the forty-five projects studied, sixteen revealed that they always have a job schedule and nine projects showed that they frequently have a job schedule. Six projects indicated that they sometimes have a job schedule, eight projects showed they rarely have a job schedule, and the remaining six never had a job schedule.

Projects that always had job schedule had a lower accident rate, whereas projects that did not have job schedule had a high accident rate. The correlation between the job schedule and the accident rate resulted in a value of $r=-0.91$; refer to Table 5.8. The negative sign represents the inverse relation between job schedule and the accident rate, while the r value represents the strength of the correlation which has a maximum value of one.

TABLE- 5.8 : THE CORRELATION BETWEEN JOB SCHEDULE AND INCIDENT RATE

Prj.	Size	SL	AR (X)	Q # 6 (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
1	S	48.54	43.00	5	14.95	223.48	-12.33	152.11	18.70	7.27	0.80	-1.7	-1.36	-0.91
2	S	78.80	28.00	20	-0.05	0.00	2.67	7.11	18.70	7.27	0.00	0.367	0.00	
3	S	53.46	51.00	10	22.95	526.67	-7.33	53.78	18.70	7.27	1.23	-1.01	-1.24	
4	S	64.85	38.60	15	10.55	111.29	-2.33	5.44	18.70	7.27	0.56	-0.32	-0.18	
5	S	85.84	21.70	20	-6.35	40.33	2.67	7.11	18.70	7.27	-0.34	0.367	-0.12	
6	S	41.97	75.76	5	47.71	2276.18	-12.33	152.11	18.70	7.27	2.55	-1.7	-4.33	
7	S	72.95	30.32	20	2.27	5.15	2.67	7.11	18.70	7.27	0.12	0.367	0.045	
8	S	66.16	32.64	15	4.59	21.06	-2.33	5.44	18.70	7.27	0.25	-0.32	-0.08	
9	S	62.73	44.40	5	16.35	267.30	-12.33	152.11	18.70	7.27	0.87	-1.7	-1.48	
10	S	64.68	38.30	15	10.25	105.05	-2.33	5.44	18.70	7.27	0.55	-0.32	-0.18	
11	S	84.33	15.25	25	-12.80	163.86	7.67	58.78	18.70	7.27	-0.68	1.054	-0.72	
12	S	84.51	15.43	20	-12.62	159.28	2.67	7.11	18.70	7.27	-0.67	0.367	-0.25	
13	S	48.61	50.50	10	22.45	503.97	-7.33	53.78	18.70	7.27	1.20	-1.01	-1.21	
14	S	89.02	11.48	25	-16.57	274.59	7.67	58.78	18.70	7.27	-0.89	1.054	-0.93	
15	S	43.68	57.61	5	29.56	873.75	-12.33	152.11	18.70	7.27	1.58	-1.7	-2.68	
16	S	46.01	48.71	10	20.66	426.81	-7.33	53.78	18.70	7.27	1.10	-1.01	-1.11	
17	S	91.62	4.41	25	-23.64	558.88	7.67	58.78	18.70	7.27	-1.26	1.054	-1.33	
18	S	51.49	55.56	15	27.51	756.76	-2.33	5.44	18.70	7.27	1.47	-0.32	-0.47	
19	S	46.43	49.00	10	20.95	438.87	-7.33	53.78	18.70	7.27	1.12	-1.01	-1.13	
20	S	97.00	3.90	20	-24.15	583.25	2.67	7.11	18.70	7.27	-1.29	0.367	-0.47	
21	M	47.86	53.00	5	24.95	622.47	-12.33	152.11	18.70	7.27	1.33	-1.7	-2.26	
22	M	55.19	50.00	10	21.95	481.77	-7.33	53.78	18.70	7.27	1.17	-1.01	-1.18	
23	M	75.18	27.16	20	-0.89	0.79	2.67	7.11	18.70	7.27	-0.05	0.367	-0.02	
24	M	72.18	18.37	25	-9.68	93.72	7.67	58.78	18.70	7.27	-0.52	1.054	-0.55	
25	M	58.19	44.64	10	16.59	275.21	-7.33	53.78	18.70	7.27	0.89	-1.01	-0.89	
26	M	57.91	45.00	10	16.95	287.28	-7.33	53.78	18.70	7.27	0.91	-1.01	-0.91	
27	M	49.34	43.16	5	15.11	228.29	-12.33	152.11	18.70	7.27	0.81	-1.7	-1.37	
28	M	83.41	23.10	20	-4.95	24.51	2.67	7.11	18.70	7.27	-0.26	0.367	-0.1	
29	M	62.24	28.00	15	-0.05	0.00	-2.33	5.44	18.70	7.27	0.00	-0.32	9E-04	
30	M	63.54	35.00	15	6.95	48.29	-2.33	5.44	18.70	7.27	0.37	-0.32	-0.12	
31	M	50.01	38.60	10	10.55	111.29	-7.33	53.78	18.70	7.27	0.56	-1.01	-0.57	
32	M	90.61	5.98	25	-22.07	487.11	7.67	58.78	18.70	7.27	-1.18	1.054	-1.24	
33	M	84.37	11.97	25	-16.08	258.59	7.67	58.78	18.70	7.27	-0.86	1.054	-0.91	
34	M	89.22	8.91	25	-19.14	366.37	7.67	58.78	18.70	7.27	-1.02	1.054	-1.08	
35	M	81.45	13.23	25	-14.82	219.65	7.67	58.78	18.70	7.27	-0.79	1.054	-0.84	
36	L	95.21	3.80	25	-24.25	588.09	7.67	58.78	18.70	7.27	-1.30	1.054	-1.37	
37	L	78.06	14.00	25	-14.05	197.42	7.67	58.78	18.70	7.27	-0.75	1.054	-0.79	
38	L	88.84	3.96	25	-24.09	580.36	7.67	58.78	18.70	7.27	-1.29	1.054	-1.36	
49	L	88.00	11.55	25	-16.50	272.27	7.67	58.78	18.70	7.27	-0.88	1.054	-0.93	
40	L	75.32	26.70	20	-1.35	1.82	2.67	7.11	18.70	7.27	-0.07	0.367	-0.03	
41	L	95.71	2.52	25	-25.53	651.81	7.67	58.78	18.70	7.27	-1.37	1.054	-1.44	
42	L	94.41	11.60	25	-16.45	270.62	7.67	58.78	18.70	7.27	-0.88	1.054	-0.93	
43	L	96.51	1.40	25	-26.65	710.26	7.67	58.78	18.70	7.27	-1.43	1.054	-1.5	
44	L	94.57	3.70	25	-24.35	592.95	7.67	58.78	18.70	7.27	-1.30	1.054	-1.37	
45	L	79.57	21.36	20	-6.69	44.77	2.67	7.11	18.70	7.27	-0.36	0.367	-0.13	
TOT.						15732.3		2380.0					-41.1	
AVG.		71.77	28.05	17										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

Q # 6 (Y) = Responses to question number 6 (Always=25, Frequently = 20, Sometimes=15, Rarely= 10, Never = 5)

5.4.3 Relationship between Planning Meetings and Accident Rates.

Again, as scheduling is important to safety, planning meetings are very important to safety and productivity. The following question was asked:

(Q # 9) Do you have a planning meeting?

Table 5.9: Project Responses to the Question of Planning Meetings

Response	No. of Projects (N)	Average safety level (SL)	Average accident rate(AR)
Always	11	88	10
Frequently	13	83	16
Sometimes	5	62	38
Rarely	10	56	45
Never	6	53	49

The results also show that the more planning meetings that are held, the safer the projects and the lower the accident rate. The correlation between planning meetings and the accident rate resulted in a value of $r = -0.84$; refer to Table 5.10. The negative sign represents the inverse relation between the planning meetings and the accident rate, while the magnitude of the r value represents the strength of the correlation which has a maximum value of one.

TABLE- 5.10 : THE CORRELATION BETWEEN PLANNING MEETINGS AND ACCIDENT RATE

Prj.	Size	SL	AR(X)	Q # 9 (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
1	S	48.54	43.00	10	14.95	223.48	-6.44	41.53	18.70	6.96	0.80	-0.93	-0.74	-0.84
2	S	78.80	28.00	10	-0.05	0.00	-6.44	41.53	18.70	6.96	0.00	-0.93	0.003	
3	S	53.46	51.00	5	22.95	526.67	-11.44	130.98	18.70	6.96	1.23	-1.64	-2.02	
4	S	64.85	38.60	15	10.55	111.29	-1.44	2.09	18.70	6.96	0.56	-0.21	-0.12	
5	S	85.84	21.70	25	-6.35	40.33	8.56	73.20	18.70	6.96	-0.34	1.229	-0.42	
6	S	41.97	75.76	5	47.71	2276.18	-11.44	130.98	18.70	6.96	2.55	-1.64	-4.19	
7	S	72.95	30.32	20	2.27	5.15	3.56	12.64	18.70	6.96	0.12	0.511	0.062	
8	S	66.16	32.64	15	4.59	21.06	-1.44	2.09	18.70	6.96	0.25	-0.21	-0.05	
9	S	62.73	44.40	5	16.35	267.30	-11.44	130.98	18.70	6.96	0.87	-1.64	-1.44	
10	S	64.68	38.30	5	10.25	105.05	-11.44	130.98	18.70	6.96	0.55	-1.64	-0.9	
11	S	84.33	15.25	20	-12.80	163.86	3.56	12.64	18.70	6.96	-0.68	0.511	-0.35	
12	S	84.51	15.43	20	-12.62	159.28	3.56	12.64	18.70	6.96	-0.67	0.511	-0.34	
13	S	48.61	50.50	10	22.45	503.97	-6.44	41.53	18.70	6.96	1.20	-0.93	-1.11	
14	S	89.02	11.48	20	-16.57	274.59	3.56	12.64	18.70	6.96	-0.89	0.511	-0.45	
15	S	43.68	57.61	10	29.56	873.75	-6.44	41.53	18.70	6.96	1.58	-0.93	-1.46	
16	S	46.01	48.71	5	20.66	426.81	-11.44	130.98	18.70	6.96	1.10	-1.64	-1.82	
17	S	91.62	4.41	25	-23.64	558.88	8.56	73.20	18.70	6.96	-1.26	1.229	-1.55	
18	S	51.49	55.56	10	27.51	756.76	-6.44	41.53	18.70	6.96	1.47	-0.93	-1.36	
19	S	46.43	49.00	10	20.95	438.87	-6.44	41.53	18.70	6.96	1.12	-0.93	-1.04	
20	S	97.00	3.90	20	-24.15	583.25	3.56	12.64	18.70	6.96	-1.29	0.511	-0.66	
21	M	47.86	53.00	10	24.95	622.47	-6.44	41.53	18.70	6.96	1.33	-0.93	-1.24	
22	M	55.19	50.00	15	21.95	481.77	-1.44	2.09	18.70	6.96	1.17	-0.21	-0.24	
23	M	75.18	27.16	10	-0.89	0.79	-6.44	41.53	18.70	6.96	-0.05	-0.93	0.044	
24	M	72.18	18.37	25	-9.68	93.72	8.56	73.20	18.70	6.96	-0.52	1.229	-0.64	
25	M	58.19	44.64	10	16.59	275.21	-6.44	41.53	18.70	6.96	0.89	-0.93	-0.82	
26	M	57.91	45.00	10	16.95	287.28	-6.44	41.53	18.70	6.96	0.91	-0.93	-0.84	
27	M	49.34	43.16	15	15.11	228.29	-1.44	2.09	18.70	6.96	0.81	-0.21	-0.17	
28	M	83.41	23.10	20	-4.95	24.51	3.56	12.64	18.70	6.96	-0.26	0.511	-0.14	
29	M	62.24	28.00	20	-0.05	0.00	3.56	12.64	18.70	6.96	0.00	0.511	-0	
30	M	63.54	35.00	20	6.95	48.29	3.56	12.64	18.70	6.96	0.37	0.511	0.19	
31	M	50.01	38.60	5	10.55	111.29	-11.44	130.98	18.70	6.96	0.56	-1.64	-0.93	
32	M	90.61	5.98	20	-22.07	487.11	3.56	12.64	18.70	6.96	-1.18	0.511	-0.6	
33	M	84.37	11.97	20	-16.08	258.59	3.56	12.64	18.70	6.96	-0.86	0.511	-0.44	
34	M	89.22	8.91	20	-19.14	366.37	3.56	12.64	18.70	6.96	-1.02	0.511	-0.52	
35	M	81.45	13.23	25	-14.82	219.65	8.56	73.20	18.70	6.96	-0.79	1.229	-0.97	
36	L	95.21	3.80	25	-24.25	588.09	8.56	73.20	18.70	6.96	-1.30	1.229	-1.59	
37	L	78.06	14.00	25	-14.05	197.42	8.56	73.20	18.70	6.96	-0.75	1.229	-0.92	
38	L	88.84	3.96	25	-24.09	580.36	8.56	73.20	18.70	6.96	-1.29	1.229	-1.58	
49	L	88.00	11.55	25	-16.50	272.27	8.56	73.20	18.70	6.96	-0.88	1.229	-1.08	
40	L	75.32	26.70	15	-1.35	1.82	-1.44	2.09	18.70	6.96	-0.07	-0.21	0.015	
41	L	95.71	2.52	25	-25.53	651.81	8.56	73.20	18.70	6.96	-1.37	1.229	-1.68	
42	L	94.41	11.60	25	-16.45	270.62	8.56	73.20	18.70	6.96	-0.88	1.229	-1.08	
43	L	96.51	1.40	20	-26.65	710.26	3.56	12.64	18.70	6.96	-1.43	0.511	-0.73	
44	L	94.57	3.70	25	-24.35	592.95	8.56	73.20	18.70	6.96	-1.30	1.229	-1.6	
45	L	79.57	21.36	20	-6.69	44.77	3.56	12.64	18.70	6.96	-0.36	0.511	-0.18	
TOT.						15732.3		2181.1					-37.7	
AVG.		71.77	28.05	16										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

Q # 9 (Y) = Responses to question number 9 (Always=25, Frequently = 20, Sometimes=15, Rarely= 10, Never = 5)

5.4.4 Relationship between Safety Meetings and Accident Rate

One of the most effective ways to promote safety awareness and minimize accident rates is holding safety meetings periodically with workers. Therefore, the following question was asked:

(Q # 14) Do you have safety meetings on this job?

Table 5.11: Project Responses to the Question of Safety Meetings

Response	No. of Projects (N)	Average safety level (SL)	Average accident rate(AR)
Always	11	91	5
Frequently	5	87	13
Sometimes	14	71	30
Rarely	6	59	39
Never	9	53	49

The results show that eleven out of the forty-five project interviewees stated that they always have safety meetings. These eleven projects had an average safety level of ninety-one and an average accident rate of five. It is clear from the table above that the more safety meetings that are held on a project, the safer it is. The correlation between safety meetings and the accident rate yielded a value of $r= -0.75$; refer to Table 5.12. The negative sign represents the inverse relation between the safety meetings and the accident rate, while the magnitude of the r value represents the strength of the correlation which has a maximum value of one

TABLE-5.12: THE CORRELATION BETWEEN SAFETY MEETINGS AND ACCIDENT RATE

Prj.	Size	SL	AR(X)	Q # 14 (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
1	S	48.54	43.00	10	14.95	223.48	-5.33	28.44	18.70	7.10	0.80	-0.75	-0.6	-0.75
2	S	78.80	28.00	15	-0.05	0.00	-0.33	0.11	18.70	7.10	0.00	-0.05	1E-04	
3	S	53.46	51.00	15	22.95	526.67	-0.33	0.11	18.70	7.10	1.23	-0.05	-0.06	
4	S	64.85	38.60	10	10.55	111.29	-5.33	28.44	18.70	7.10	0.56	-0.75	-0.42	
5	S	85.84	21.70	15	-6.35	40.33	-0.33	0.11	18.70	7.10	-0.34	-0.05	0.016	
6	S	41.97	75.76	5	47.71	2276.18	-10.33	106.78	18.70	7.10	2.55	-1.45	-3.71	
7	S	72.95	30.32	15	2.27	5.15	-0.33	0.11	18.70	7.10	0.12	-0.05	-0.01	
8	S	66.16	32.64	10	4.59	21.06	-5.33	28.44	18.70	7.10	0.25	-0.75	-0.18	
9	S	62.73	44.40	5	16.35	267.30	-10.33	106.78	18.70	7.10	0.87	-1.45	-1.27	
10	S	64.68	38.30	15	10.25	105.05	-0.33	0.11	18.70	7.10	0.55	-0.05	-0.03	
11	S	84.33	15.25	25	-12.80	163.86	9.67	93.44	18.70	7.10	-0.68	1.361	-0.93	
12	S	84.51	15.43	25	-12.62	159.28	9.67	93.44	18.70	7.10	-0.67	1.361	-0.92	
13	S	48.61	50.50	5	22.45	503.97	-10.33	106.78	18.70	7.10	1.20	-1.45	-1.75	
14	S	89.02	11.48	15	-16.57	274.59	-0.33	0.11	18.70	7.10	-0.89	-0.05	0.042	
15	S	43.68	57.61	10	29.56	873.75	-5.33	28.44	18.70	7.10	1.58	-0.75	-1.19	
16	S	46.01	48.71	15	20.66	426.81	-0.33	0.11	18.70	7.10	1.10	-0.05	-0.05	
17	S	91.62	4.41	20	-23.64	558.88	4.67	21.78	18.70	7.10	-1.26	0.657	-0.83	
18	S	51.49	55.56	15	27.51	756.76	-0.33	0.11	18.70	7.10	1.47	-0.05	-0.07	
19	S	46.43	49.00	5	20.95	438.87	-10.33	106.78	18.70	7.10	1.12	-1.45	-1.63	
20	S	97.00	3.90	25	-24.15	583.25	9.67	93.44	18.70	7.10	-1.29	1.361	-1.76	
21	M	47.86	53.00	5	24.95	622.47	-10.33	106.78	18.70	7.10	1.33	-1.45	-1.94	
22	M	55.19	50.00	5	21.95	481.77	-10.33	106.78	18.70	7.10	1.17	-1.45	-1.71	
23	M	75.18	27.16	25	-0.89	0.79	9.67	93.44	18.70	7.10	-0.05	1.361	-0.06	
24	M	72.18	18.37	15	-9.68	93.72	-0.33	0.11	18.70	7.10	-0.52	-0.05	0.024	
25	M	58.19	44.64	15	16.59	275.21	-0.33	0.11	18.70	7.10	0.89	-0.05	-0.04	
26	M	57.91	45.00	5	16.95	287.28	-10.33	106.78	18.70	7.10	0.91	-1.45	-1.32	
27	M	49.34	43.16	10	15.11	228.29	-5.33	28.44	18.70	7.10	0.81	-0.75	-0.61	
28	M	83.41	23.10	25	-4.95	24.51	9.67	93.44	18.70	7.10	-0.26	1.361	-0.36	
29	M	62.24	28.00	15	-0.05	0.00	-0.33	0.11	18.70	7.10	0.00	-0.05	1E-04	
30	M	63.54	35.00	5	6.95	48.29	-10.33	106.78	18.70	7.10	0.37	-1.45	-0.54	
31	M	50.01	38.60	5	10.55	111.29	-10.33	106.78	18.70	7.10	0.56	-1.45	-0.82	
32	M	90.61	5.98	25	-22.07	487.11	9.67	93.44	18.70	7.10	-1.18	1.361	-1.61	
33	M	84.37	11.97	25	-16.08	258.59	9.67	93.44	18.70	7.10	-0.86	1.361	-1.17	
34	M	89.22	8.91	25	-19.14	366.37	9.67	93.44	18.70	7.10	-1.02	1.361	-1.39	
35	M	81.45	13.23	25	-14.82	219.65	9.67	93.44	18.70	7.10	-0.79	1.361	-1.08	
36	L	95.21	3.80	15	-24.25	588.09	-0.33	0.11	18.70	7.10	-1.30	-0.05	0.061	
37	L	78.06	14.00	20	-14.05	197.42	4.67	21.78	18.70	7.10	-0.75	0.657	-0.49	
38	L	88.84	3.96	25	-24.09	580.36	9.67	93.44	18.70	7.10	-1.29	1.361	-1.75	
49	L	88.00	11.55	15	-16.50	272.27	-0.33	0.11	18.70	7.10	-0.88	-0.05	0.041	
40	L	75.32	26.70	15	-1.35	1.82	-0.33	0.11	18.70	7.10	-0.07	-0.05	0.003	
41	L	95.71	2.52	20	-25.53	651.81	4.67	21.78	18.70	7.10	-1.37	0.657	-0.9	
42	L	94.41	11.60	25	-16.45	270.62	9.67	93.44	18.70	7.10	-0.88	1.361	-1.2	
43	L	96.51	1.40	20	-26.65	710.26	4.67	21.78	18.70	7.10	-1.43	0.657	-0.94	
44	L	94.57	3.70	20	-24.35	592.95	4.67	21.78	18.70	7.10	-1.30	0.657	-0.86	
45	L	79.57	21.36	10	-6.69	44.77	-5.33	28.44	18.70	7.10	-0.36	-0.75	0.269	
TOT.						15732.3		2270.0					-33.7	
AVG.		71.77	28.05	15										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

Q # 14 (Y) = Responses to question number 14 (Always=25, Frequently = 20, Sometimes=15, Rarely= 10, Never = 5)

5.4.5 Relationship between Safety Accountability and Accident Rate.

Another important factor that has a great effect on safety is accountability. People tend to be complacent if they think they will not be reprimanded or held responsible for their acts. Therefore, the following question was asked:

(Q # 18) Are you evaluated at all in terms of your safety record?

Table 5.13: Project Responses to the Question of Safety Accountability

Response	No. of Projects (N)	Average safety level (SL)	Average accident rate(AR)
Always	5	90	10
Frequently	8	88	11
Sometimes	16	69	32
Rarely	9	65	35
Never	7	56	43

The result shows that when the project engineer, or the project manager, believes that the safety of the project is part of his performance evaluation by his superior, the safety level in these projects will increase. Consequently the average accident rate will decrease. The correlation between safety accountability and accident rate resulted in a value of r=-0.59 ; refer to Table 5.14. The negative sign represents the inverse relation between safety accountability and accident rate, while the magnitude of the r value represents the strength of the correlation which has a maximum value of one.

TABLE- 5.14 : THE CORRELATION BETWEEN SAFETY ACCOUNTABILITY AND ACCIDENT RATE

Prj.	Size	SL	AR(X)	Q # 18 (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
1	S	48.54	43.00	5	14.95	223.48	-9.44	89.20	18.70	5.98	0.80	-1.58	-1.26	-0.59
2	S	78.80	28.00	5	-0.05	0.00	-9.44	89.20	18.70	5.98	0.00	-1.58	0.004	
3	S	53.46	51.00	10	22.95	526.67	-4.44	19.75	18.70	5.98	1.23	-0.74	-0.91	
4	S	64.85	38.60	15	10.55	111.29	0.56	0.31	18.70	5.98	0.56	0.093	0.052	
5	S	85.84	21.70	15	-6.35	40.33	0.56	0.31	18.70	5.98	-0.34	0.093	-0.03	
6	S	41.97	75.76	10	47.71	2276.18	-4.44	19.75	18.70	5.98	2.55	-0.74	-1.9	
7	S	72.95	30.32	15	2.27	5.15	0.56	0.31	18.70	5.98	0.12	0.093	0.011	
8	S	66.16	32.64	10	4.59	21.06	-4.44	19.75	18.70	5.98	0.25	-0.74	-0.18	
9	S	62.73	44.40	15	16.35	267.30	0.56	0.31	18.70	5.98	0.87	0.093	0.081	
10	S	64.68	38.30	10	10.25	105.05	-4.44	19.75	18.70	5.98	0.55	-0.74	-0.41	
11	S	84.33	15.25	15	-12.80	163.86	0.56	0.31	18.70	5.98	-0.68	0.093	-0.06	
12	S	84.51	15.43	20	-12.62	159.28	5.56	30.86	18.70	5.98	-0.67	0.928	-0.63	
13	S	48.61	50.50	15	22.45	503.97	0.56	0.31	18.70	5.98	1.20	0.093	0.111	
14	S	89.02	11.48	25	-16.57	274.59	10.56	111.42	18.70	5.98	-0.89	1.764	-1.56	
15	S	43.68	57.61	15	29.56	873.75	0.56	0.31	18.70	5.98	1.58	0.093	0.147	
16	S	46.01	48.71	15	20.66	426.81	0.56	0.31	18.70	5.98	1.10	0.093	0.103	
17	S	91.62	4.41	10	-23.64	558.88	-4.44	19.75	18.70	5.98	-1.26	-0.74	0.939	
18	S	51.49	55.56	15	27.51	756.76	0.56	0.31	18.70	5.98	1.47	0.093	0.137	
19	S	46.43	49.00	5	20.95	438.87	-9.44	89.20	18.70	5.98	1.12	-1.58	-1.77	
20	S	97.00	3.90	25	-24.15	583.25	10.56	111.42	18.70	5.98	-1.29	1.764	-2.28	
21	M	47.86	53.00	10	24.95	622.47	-4.44	19.75	18.70	5.98	1.33	-0.74	-0.99	
22	M	55.19	50.00	5	21.95	481.77	-9.44	89.20	18.70	5.98	1.17	-1.58	-1.85	
23	M	75.18	27.16	25	-0.89	0.79	10.56	111.42	18.70	5.98	-0.05	1.764	-0.08	
24	M	72.18	18.37	20	-9.68	93.72	5.56	30.86	18.70	5.98	-0.52	0.928	-0.48	
25	M	58.19	44.64	5	16.59	275.21	-9.44	89.20	18.70	5.98	0.89	-1.58	-1.4	
26	M	57.91	45.00	5	16.95	287.28	-9.44	89.20	18.70	5.98	0.91	-1.58	-1.43	
27	M	49.34	43.16	5	15.11	228.29	-9.44	89.20	18.70	5.98	0.81	-1.58	-1.28	
28	M	83.41	23.10	15	-4.95	24.51	0.56	0.31	18.70	5.98	-0.26	0.093	-0.02	
29	M	62.24	28.00	15	-0.05	0.00	0.56	0.31	18.70	5.98	0.00	0.093	-0	
30	M	63.54	35.00	15	6.95	48.29	0.56	0.31	18.70	5.98	0.37	0.093	0.035	
31	M	50.01	38.60	10	10.55	111.29	-4.44	19.75	18.70	5.98	0.56	-0.74	-0.42	
32	M	90.61	5.98	20	-22.07	487.11	5.56	30.86	18.70	5.98	-1.18	0.928	-1.1	
33	M	84.37	11.97	15	-16.08	258.59	0.56	0.31	18.70	5.98	-0.86	0.093	-0.08	
34	M	89.22	8.91	20	-19.14	366.37	5.56	30.86	18.70	5.98	-1.02	0.928	-0.95	
35	M	81.45	13.23	20	-14.82	219.65	5.56	30.86	18.70	5.98	-0.79	0.928	-0.74	
36	L	95.21	3.80	20	-24.25	588.09	5.56	30.86	18.70	5.98	-1.30	0.928	-1.2	
37	L	78.06	14.00	15	-14.05	197.42	0.56	0.31	18.70	5.98	-0.75	0.093	-0.07	
38	L	88.84	3.96	10	-24.09	580.36	-4.44	19.75	18.70	5.98	-1.29	-0.74	0.957	
49	L	88.00	11.55	25	-16.50	272.27	10.56	111.42	18.70	5.98	-0.88	1.764	-1.56	
40	L	75.32	26.70	15	-1.35	1.82	0.56	0.31	18.70	5.98	-0.07	0.093	-0.01	
41	L	95.71	2.52	20	-25.53	651.81	5.56	30.86	18.70	5.98	-1.37	0.928	-1.27	
42	L	94.41	11.60	20	-16.45	270.62	5.56	30.86	18.70	5.98	-0.88	0.928	-0.82	
43	L	96.51	1.40	25	-26.65	710.26	10.56	111.42	18.70	5.98	-1.43	1.764	-2.51	
44	L	94.57	3.70	15	-24.35	592.95	0.56	0.31	18.70	5.98	-1.30	0.093	-0.12	
45	L	79.57	21.36	10	-6.69	44.77	-4.44	19.75	18.70	5.98	-0.36	-0.74	0.266	
TOT.						15732.3		1611.1					-26.5	
AVG.		71.77	28.05	14										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

Q # 18 (Y) = Responses to question number 18 (Always=25, Frequently = 20, Sometimes=15, Rarely= 10, Never = 5)

5.4.6 *Relationship between Workers' Experience and Accident Rate.*

It is almost a universal policy for all companies to keep hard workers with a good safety record on their payroll for many years.

This type of worker develops a sense of loyalty to the company and has a greater sense of pride in workmanship. To evaluate the effect of long-hired workers on safety, the following question was asked:

(Q # 21) How many of your men have worked for you on other jobs?

Table 5.15: Project Responses to the Question of Maintaining Previously Hired Workers

Response	No. of Projects (N)	Average safety level (SL)	Average accident rate(AR)
Over 75%	12	78	21
50% to 75%	12	73	29
25% to 50%	11	70	29
10% to 25%	6	68	28
0% to 10%	3	60	45

The results show that projects where over 75% of their employees are long-hired have a lower accident rate. Furthermore, as this percentage decreases, the average accident rate increases. The correlation between workers' experience and the accident rate results in a value of r= -0.24 ; refer to Table 5.16. The negative sign represents the inverse relation between the workers' experience and the accident rate, while the magnitude of the r value represents the strength of the correlation which has a maximum value of one.

TABLE- 5.16 : THE CORRELATION BETWEEN WORKERS' EXPERIENCE AND ACCIDENT RATE

Prj.	Size	SL	AR(X)	Q # 21 (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
1	S	48.54	43.00	10	14.95	223.48	-7.56	57.09	18.70	6.11	0.80	-1.24	-0.99	-0.24
2	S	78.80	28.00	5	-0.05	0.00	-12.56	157.64	18.70	6.11	0.00	-2.05	0.006	
3	S	53.46	51.00	20	22.95	526.67	2.44	5.98	18.70	6.11	1.23	0.4	0.491	
4	S	64.85	38.60	25	10.55	111.29	7.44	55.42	18.70	6.11	0.56	1.218	0.687	
5	S	85.84	21.70	15	-6.35	40.33	-2.56	6.53	18.70	6.11	-0.34	-0.42	0.142	
6	S	41.97	75.76	20	47.71	2276.18	2.44	5.98	18.70	6.11	2.55	0.4	1.02	
7	S	72.95	30.32	10	2.27	5.15	-7.56	57.09	18.70	6.11	0.12	-1.24	-0.15	
8	S	66.16	32.64	15	4.59	21.06	-2.56	6.53	18.70	6.11	0.25	-0.42	-0.1	
9	S	62.73	44.40	25	16.35	267.30	7.44	55.42	18.70	6.11	0.87	1.218	1.065	
10	S	64.68	38.30	20	10.25	105.05	2.44	5.98	18.70	6.11	0.55	0.4	0.219	
11	S	84.33	15.25	25	-12.80	163.86	7.44	55.42	18.70	6.11	-0.68	1.218	-0.83	
12	S	84.51	15.43	25	-12.62	159.28	7.44	55.42	18.70	6.11	-0.67	1.218	-0.82	
13	S	48.61	50.50	5	22.45	503.97	-12.56	157.64	18.70	6.11	1.20	-2.05	-2.47	
14	S	89.02	11.48	20	-16.57	274.59	2.44	5.98	18.70	6.11	-0.89	0.4	-0.35	
15	S	43.68	57.61	15	29.56	873.75	-2.56	6.53	18.70	6.11	1.58	-0.42	-0.66	
16	S	46.01	48.71	20	20.66	426.81	2.44	5.98	18.70	6.11	1.10	0.4	0.442	
17	S	91.62	4.41	10	-23.64	558.88	-7.56	57.09	18.70	6.11	-1.26	-1.24	1.563	
18	S	51.49	55.56	5	27.51	756.76	-12.56	157.64	18.70	6.11	1.47	-2.05	-3.02	
19	S	46.43	49.00	10	20.95	438.87	-7.56	57.09	18.70	6.11	1.12	-1.24	-1.39	
20	S	97.00	3.90	25	-24.15	583.25	7.44	55.42	18.70	6.11	-1.29	1.218	-1.57	
21	M	47.86	53.00	15	24.95	622.47	-2.56	6.53	18.70	6.11	1.33	-0.42	-0.56	
22	M	55.19	50.00	25	21.95	481.77	7.44	55.42	18.70	6.11	1.17	1.218	1.43	
23	M	75.18	27.16	20	-0.89	0.79	2.44	5.98	18.70	6.11	-0.05	0.4	-0.02	
24	M	72.18	18.37	15	-9.68	93.72	-2.56	6.53	18.70	6.11	-0.52	-0.42	0.216	
25	M	58.19	44.64	20	16.59	275.21	2.44	5.98	18.70	6.11	0.89	0.4	0.355	
26	M	57.91	45.00	15	16.95	287.28	-2.56	6.53	18.70	6.11	0.91	-0.42	-0.38	
27	M	49.34	43.16	15	15.11	228.29	-2.56	6.53	18.70	6.11	0.81	-0.42	-0.34	
28	M	83.41	23.10	15	-4.95	24.51	-2.56	6.53	18.70	6.11	-0.26	-0.42	0.111	
29	M	62.24	28.00	25	-0.05	0.00	7.44	55.42	18.70	6.11	0.00	1.218	-0	
30	M	63.54	35.00	20	6.95	48.29	2.44	5.98	18.70	6.11	0.37	0.4	0.149	
31	M	50.01	38.60	10	10.55	111.29	-7.56	57.09	18.70	6.11	0.56	-1.24	-0.7	
32	M	90.61	5.98	25	-22.07	487.11	7.44	55.42	18.70	6.11	-1.18	1.218	-1.44	
33	M	84.37	11.97	25	-16.08	258.59	7.44	55.42	18.70	6.11	-0.86	1.218	-1.05	
34	M	89.22	8.91	25	-19.14	366.37	7.44	55.42	18.70	6.11	-1.02	1.218	-1.25	
35	M	81.45	13.23	25	-14.82	219.65	7.44	55.42	18.70	6.11	-0.79	1.218	-0.97	
36	L	95.21	3.80	15	-24.25	588.09	-2.56	6.53	18.70	6.11	-1.30	-0.42	0.542	
37	L	78.06	14.00	15	-14.05	197.42	-2.56	6.53	18.70	6.11	-0.75	-0.42	0.314	
38	L	88.84	3.96	10	-24.09	580.36	-7.56	57.09	18.70	6.11	-1.29	-1.24	1.593	
49	L	88.00	11.55	15	-16.50	272.27	-2.56	6.53	18.70	6.11	-0.88	-0.42	0.369	
40	L	75.32	26.70	10	-1.35	1.82	-7.56	57.09	18.70	6.11	-0.07	-1.24	0.089	
41	L	95.71	2.52	20	-25.53	651.81	2.44	5.98	18.70	6.11	-1.37	0.4	-0.55	
42	L	94.41	11.60	20	-16.45	270.62	2.44	5.98	18.70	6.11	-0.88	0.4	-0.35	
43	L	96.51	1.40	20	-26.65	710.26	2.44	5.98	18.70	6.11	-1.43	0.4	-0.57	
44	L	94.57	3.70	20	-24.35	592.95	2.44	5.98	18.70	6.11	-1.30	0.4	-0.52	
45	L	79.57	21.36	25	-6.69	44.77	7.44	55.42	18.70	6.11	-0.36	1.218	-0.44	
TOT.					-28.05	15732.3		1681.1					-10.7	
AVG.		71.77	28.05	18										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

Q # 21 (Y) = Responses to question number 21 (Always = 25, Frequently = 20, Sometimes = 15, Rarely = 10, Never = 5)

5.4.7 Relationship between Training New Workers and Accident Rate.

Most accidents are caused by new workers either because of their inexperience of the field or their lack of familiarity with the new environment. One of the most important roles of job supervision in terms of personal relations is to help new workers become oriented to their new environment. Therefore, the following question was asked:

(Q # 22) Do you ever get involved with new workers?

Table 5.17: Project Responses to the Question of Training New Workers

Response	No. of Projects (N)	Average safety level (SL)	Average accident rate(AR)
Always	7	89	11
Frequently	8	86	14
Sometimes	24	65	34
Rarely	5	55	47
Never	1	79	28

The result shows that projects that have management which cares about new workers have a high average safety level and a low average accident rate. The more management gets involved with new workers, the fewer accidents they have. The correlation between training new workers and the accident rate resulted in a value of $r=-0.56$; refer to Table 5.18. The negative sign represents the inverse relation between the training new workers and the accident rate, while the magnitude of the r value represents the strength of the correlation which has a maximum value of one.

TABLE- 5.18 : THE CORRELATION BETWEEN TRAINING NEW WORKERS AND ACCIDENT RATE

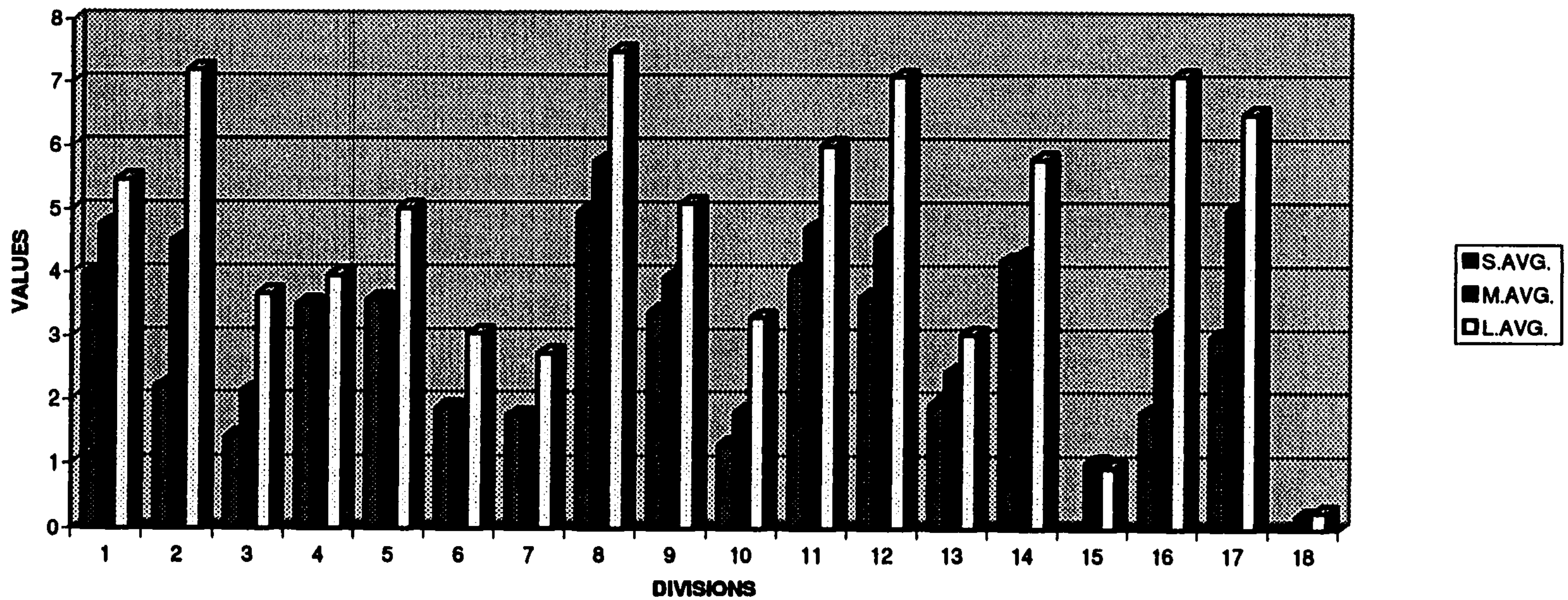
Prj.	Size	SL	AR(X)	Q # 22 (Y)	(X-Mx)	$(X-Mx)^2$	(Y-My)	$(Y-My)^2$	σX	σy	Zx	Zy	ZxZy	r
1	S	48.54	43.00	15	14.95	223.48	-1.67	2.78	18.70	4.71	0.80	-0.35	-0.28	-0.56
2	S	78.80	28.00	5	-0.05	0.00	-11.67	136.11	18.70	4.71	0.00	-2.47	0.007	
3	S	53.46	51.00	10	22.95	526.67	-6.67	44.44	18.70	4.71	1.23	-1.41	-1.74	
4	S	64.85	38.60	15	10.55	111.29	-1.67	2.78	18.70	4.71	0.56	-0.35	-0.2	
5	S	85.84	21.70	15	-6.35	40.33	-1.67	2.78	18.70	4.71	-0.34	-0.35	0.12	
6	S	41.97	75.76	15	47.71	2276.18	-1.67	2.78	18.70	4.71	2.55	-0.35	-0.9	
7	S	72.95	30.32	20	2.27	5.15	3.33	11.11	18.70	4.71	0.12	0.707	0.086	
8	S	66.16	32.64	10	4.59	21.06	-6.67	44.44	18.70	4.71	0.25	-1.41	-0.35	
9	S	62.73	44.40	20	16.35	267.30	3.33	11.11	18.70	4.71	0.87	0.707	0.618	
10	S	64.68	38.30	15	10.25	105.05	-1.67	2.78	18.70	4.71	0.55	-0.35	-0.19	
11	S	84.33	15.25	15	-12.80	163.86	-1.67	2.78	18.70	4.71	-0.68	-0.35	0.242	
12	S	84.51	15.43	15	-12.62	159.28	-1.67	2.78	18.70	4.71	-0.67	-0.35	0.239	
13	S	48.61	50.50	15	22.45	503.97	-1.67	2.78	18.70	4.71	1.20	-0.35	-0.42	
14	S	89.02	11.48	20	-16.57	274.59	3.33	11.11	18.70	4.71	-0.89	0.707	-0.63	
15	S	43.68	57.61	15	29.56	873.75	-1.67	2.78	18.70	4.71	1.58	-0.35	-0.56	
16	S	46.01	48.71	15	20.66	426.81	-1.67	2.78	18.70	4.71	1.10	-0.35	-0.39	
17	S	91.62	4.41	15	-23.64	558.88	-1.67	2.78	18.70	4.71	-1.26	-0.35	0.447	
18	S	51.49	55.56	10	27.51	756.76	-6.67	44.44	18.70	4.71	1.47	-1.41	-2.08	
19	S	46.43	49.00	15	20.95	438.87	-1.67	2.78	18.70	4.71	1.12	-0.35	-0.4	
20	S	97.00	3.90	25	-24.15	583.25	8.33	69.44	18.70	4.71	-1.29	1.768	-2.28	
21	M	47.86	53.00	10	24.95	622.47	-6.67	44.44	18.70	4.71	1.33	-1.41	-1.89	
22	M	55.19	50.00	15	21.95	481.77	-1.67	2.78	18.70	4.71	1.17	-0.35	-0.42	
23	M	75.18	27.16	15	-0.89	0.79	-1.67	2.78	18.70	4.71	-0.05	-0.35	0.017	
24	M	72.18	18.37	15	-9.68	93.72	-1.67	2.78	18.70	4.71	-0.52	-0.35	0.183	
25	M	58.19	44.64	15	16.59	275.21	-1.67	2.78	18.70	4.71	0.89	-0.35	-0.31	
26	M	57.91	45.00	10	16.95	287.28	-6.67	44.44	18.70	4.71	0.91	-1.41	-1.28	
27	M	49.34	43.16	15	15.11	228.29	-1.67	2.78	18.70	4.71	0.81	-0.35	-0.29	
28	M	83.41	23.10	25	-4.95	24.51	8.33	69.44	18.70	4.71	-0.26	1.768	-0.47	
29	M	62.24	28.00	15	-0.05	0.00	-1.67	2.78	18.70	4.71	0.00	-0.35	1E-03	
30	M	63.54	35.00	15	6.95	48.29	-1.67	2.78	18.70	4.71	0.37	-0.35	-0.13	
31	M	50.01	38.60	15	10.55	111.29	-1.67	2.78	18.70	4.71	0.56	-0.35	-0.2	
32	M	90.61	5.98	25	-22.07	487.11	8.33	69.44	18.70	4.71	-1.18	1.768	-2.09	
33	M	84.37	11.97	20	-16.08	258.59	3.33	11.11	18.70	4.71	-0.86	0.707	-0.61	
34	M	89.22	8.91	25	-19.14	366.37	8.33	69.44	18.70	4.71	-1.02	1.768	-1.81	
35	M	81.45	13.23	15	-14.82	219.65	-1.67	2.78	18.70	4.71	-0.79	-0.35	0.28	
36	L	95.21	3.80	20	-24.25	588.09	3.33	11.11	18.70	4.71	-1.30	0.707	-0.92	
37	L	78.06	14.00	25	-14.05	197.42	8.33	69.44	18.70	4.71	-0.75	1.768	-1.33	
38	L	88.84	3.96	15	-24.09	580.36	-1.67	2.78	18.70	4.71	-1.29	-0.35	0.456	
49	L	88.00	11.55	25	-16.50	272.27	8.33	69.44	18.70	4.71	-0.88	1.768	-1.56	
40	L	75.32	26.70	15	-1.35	1.82	-1.67	2.78	18.70	4.71	-0.07	-0.35	0.026	
41	L	95.71	2.52	20	-25.53	651.81	3.33	11.11	18.70	4.71	-1.37	0.707	-0.97	
42	L	94.41	11.60	25	-16.45	270.62	8.33	69.44	18.70	4.71	-0.88	1.768	-1.56	
43	L	96.51	1.40	20	-26.65	710.26	3.33	11.11	18.70	4.71	-1.43	0.707	-1.01	
44	L	94.57	3.70	20	-24.35	592.95	3.33	11.11	18.70	4.71	-1.30	0.707	-0.92	
45	L	79.57	21.36	15	-6.69	44.77	-1.67	2.78	18.70	4.71	-0.36	-0.35	0.127	
TOT.						15732.3		1000.0					-25.3	
AVG.		71.77	28.05	17										

SL=Safety level AR=accident rate Mx=Mean value of X σX= Standard deviation of X S = Small

(X-Mx)2 = Square of value X minus its mean r = Correlation between the values of X and Y M = Medium L= Large

Q # 22 (Y) = Responses to question number 22 (Always=25, Frequently = 20, Sometimes=15, Rarely= 10, Never = 5)

FIGURE 5.5 : AVERAGE ACTIVITY VALUES IN SMALL, MEDIUM AND LARGE PROJECTS



1- Site Layout & House keeping
2- Protective Equipment & Site Safety Admin.
3- Fire Prevention
4- Transportaion
5- Excavation & shoring
6- Welding and cutting
7- Compressed Gas.
8- Scaffolding
9- Hand tools & Power tools
10- Cartridge Oper. tools
11- Concrete formwork
12- Cranes and Lifting devices
13- Air compressors
14- Electrical
15- Blasting
16-Welfare facilities
17- Heavy Equipment
18- Chemical

S.AVG.= Average in small projects
M.AVG.= Average in medium projects
L.AVG .= Average in large projects

The table below shows the (25) safe projects , which had fewer accidents and a safety level higher than the average safety level for all projects.

Table 5.19: Safe Projects

Project #	AR (X)	SL (Y)	Size
Project # 43	1	97	Large
Project # 41	3	96	Large
Project # 44	4	95	Large
Project # 36	4	95	Large
Project # 20	4	97	Small
Project # 38	4	89	Large
Project # 17	4	92	Small
Project # 32	6	91	Medium
Project # 34	9	89	Medium
Project # 14	11	89	Small
Project # 49	12	88	Large
Project # 42	12	94	Large
Project # 33	12	84	Medium
Project # 35	13	81	Medium
Project # 37	14	78	Large
Project # 11	15	84	Small
Project # 12	15	85	Small
Project # 24	18	72	Medium
Project # 45	21	80	Large
Project # 5	22	86	Small
Project # 28	23	83	Medium
Project # 40	27	75	Large
Project # 23	27	75	Medium
Project # 2	28	79	Small
Project # 29	28	62	Medium
TOTAL	337	2136	
AVERAGE	13.48	85.44	

The table below shows the (20) unsafe projects , which had more accidents and a safety level less than the average safety level for all projects.

Table 5.20: Unsafe Projects

Project #	AR	SL(Y)	Size
Project # 7	30	73	Small
Project # 8	33	66	Small
Project # 30	35	64	Medium
Project # 10	38	65	Small
Project # 4	39	65	Small
Project # 31	39	50	Medium
Project # 1	43	49	Small
Project # 27	43	49	Medium
Project # 9	44	63	Small
Project # 25	45	58	Medium
Project # 26	45	58	Medium
Project # 16	49	46	Small
Project # 19	49	46	Small
Project # 22	50	55	Medium
Project # 13	51	49	Small
Project # 3	51	53	Small
Project # 21	53	48	Medium
Project # 18	56	51	Small
Project # 15	58	44	Small
Project # 6	76	42	Small
TOTAL	927	1094	
AVERAGE	46	55	

5.5 TEST OF HYPOTHESIS

The "t-test" is utilized to test the hypothesis that a linear relationship exists between accident rate and each of the following items:

1-* Safety level in the project (SL)

2- * Assigned safety officer

3- * Job schedule

4- * Planning meetings

5- * Safety meetings

6- * Safety accountability

7- * Worker experience

8- * Training new workers

It is intended here to test the correlation between the above items and the accident rate. The null hypothesis is tested by comparing the values of the test statistic (t) for the eight items above with the critical test value. If X represents the accident rate and Y represents the value of each of the above eight items at a time of testing, then $Y = \beta_0 + \beta_1 X$ where β_0 = Y intercept and β_1 = slope of the line. If there is no linear relationship, then the slope will be equal to zero, so we wish to test the null hypothesis, $H_0 : \beta_1 = 0$ against $H_a : \beta_1 \neq 0$

The null hypothesis states that there is no relation between accident rate and the eight above items; therefore, there is no correlation between them ($r = 0$).

To calculate the value of "t"

$$\text{Test statistics: } t = \frac{\hat{B}_i - B_{1,0}}{S}\sqrt{SSx}$$

The least squares estimators for B_0 and B_1

$$SSx = \sum_{i=1}^{n} X_i^2 - \left(\frac{\sum_{i=1}^{n} X_i}{n}\right)^2$$

$$SSy = \sum_{i=1}^{n} y_i^2 - \left(\frac{\sum_{i=1}^{n} y_i}{n}\right)^2$$

$$SSxy = \sum_{i=1}^{n} x_i y_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{n}$$

$$\hat{B}_1 = \frac{SS_{xy}}{SS_x} \quad \hat{B}_0 = \bar{y} - \hat{B}_1 \bar{X}$$

$$SSE = SSy - \hat{B}_1 SS_{xy}$$

$$S^2 = \frac{SSE}{n-2}$$

The number of data point $n = 45$

The critical value of t is obtained from the t table using $(n-2) = 43$ degree of freedom and $\alpha = 0.05$. Since it is a two-tailed test, then $\alpha/2$ is used. The critical value of t is equal to 1.96 .

SSE = Sum of squares for error.

SSx = Sum of squares for X

SSy = Sum of squares for y

$SSxy$ = Sum of squares for xy

$\hat{B}_0$ = Represents estimate of y intercept

$\hat{B}_1$ = Represents estimate for the slope of the line

Table 5. 21: Represents the Test Statistic t Values

Item	t Values
Safety level	-20.9
Safety officer	-2.32
Job schedule	-2.98
Planning meetings	-2.20
Safety meetings	-7.43
Safety accountability	-4.79
Workers experience	-2.1
Training new workers	-4.46

Comparison of the "t" values of the table with the critical test value ($t > 1.960$ or $t < -1.960$) reveals that all values are greater than the critical test value. This refutes the null hypothesis and asserts that there is a linear relation between the accident rate and the eight items mentioned previously.

CHAPTER 6

CONCLUSION

6.1 GENERAL

The results of the survey show that the average accident rate is 28 and the average safety level is 72 for all the 45 small, medium and large projects.

14 of these projects were rated poor, 6 were rated fair, 10 were rated very good, 7 were rated good and 8 were rated excellent.

6.2 LARGE PROJECTS

There were ten large projects surveyed, each with a minimum value of twenty million Saudi Riyals. Six projects of this group had an excellent rating, which corresponds to a safety level between 90 percent and 100 percent. Two projects had a very good rating, which corresponds to safety level of 80 percent to 90 percent. The other two had a good rating, which corresponds to a safety level of 70 percent to 80 percent.

As the safety level increased in these projects, the accident rate decreased. There was an inverse relation between these two items and also a high correlation, as is shown in the data analysis tables.

Seven out of the ten projects which have an excellent rating had an assigned safety officer within their companies, which was a major contribution to the accident rate reduction.

Furthermore, eight projects of this group stated that they always have a job schedule and they do their best to follow and meet the schedule. The other two projects stated that they frequently have a schedule. This is the second highest answer.

6.3 MEDIUM PROJECTS

There are a total of fifteen projects in this group. One medium project had an excellent rating, corresponding to a 90 safety level and a 5 accident rate. Four medium projects had a very good rating corresponding to a safety level from 80 to 90 percent. The accident rate in these projects ranges from 8 to 23. One project had a good rating with a safety level of seventy-five (75) and an accident rate of twenty-seven (27).

Two projects of this group were rated fair, with safety levels of sixty-three (63) and sixty-two (62), corresponding to an accident rate of twenty-eight (28) and thirty-five (35) respectively.

Five medium projects were rated poor, with safety levels ranging from forty-seven (47) to fifty (50). The accident rate ranged from thirty-eight (38) to fifty three (53).

6.4 SMALL PROJECTS

There are a total of twenty projects in this group. One of these projects had an excellent rating, with a safety level of ninety-one (91) and an accident rate of four.

Four projects of this group had a very good rating, with safety levels ranging from eighty to ninety percent and a corresponding accident rate ranging from eleven to twenty-one.

Two projects of this group were rated good. One had a safety level of seventy-eight and the other had a safety level of seventy-two. The accident rates for these two projects were twenty-eight (28) and thirty (30) respectively.

Four projects of this group were rated fair, with safety levels ranging from sixty-two (62) to sixty-four (64). The accident rate in these projects ranged from thirty-two (32) to thirty-four (34).

Nine projects of this group were rated poor with a safety level ranging from forty-three (43) to fifty-seven (57).

6.5 SAFE PROJECTS

Projects that have an accident rate equal to, or less than, the average accident rate are classified as safe projects. This group has a total of twenty five projects and the majority of this group are medium and large projects. Moreover, the average accident rate in this group is 13.48, which is almost half the accident rate for the total sample, and its average safety level is 85.44.

6.6 UNSAFE PROJECTS

These are projects that have an accident rate above the average. This group has a total of twenty projects with an average accident rate of 46, which is about sixty percent higher than the accident rate for the total sample. Moreover, the average safety level was found to be 55, which is a lot less than the average of the total sample. The majority of this group are small projects. This indicates that small projects care less about safety while medium and large projects have better safety programs.

6.7 MIDDLE-MANAGEMENT PARTICIPATION IN THE SAFETY SYSTEM

Safety is one of the primary functions and duties of middle management within any organization or company. Their interest in safety is transmitted to workers through different channels and in different ways. This has become evident from the answers to the questionnaire that were asked in each project.

The effect of an assigned safety officer on accident rate and safety level was very clear. Projects that always had designated safety officers had an average safety level and an average accident rate of 93 and 5 respectively. In contrast, projects that had never had assigned safety officers had an average safety level and average accident rate of 50 and 51 respectively. Refer to Table 5.5.

The results are not surprising. The safety officer in a company or project, as a staff person, has no administrative power over the operating components of the organization. He is only charged with organizing, stimulating and guiding the safety program as well as being a safety reference for all those involved in the work.

His efforts in pointing out dangerous actions that could lead to accidents and in educating workers, either by providing safety films or hanging posters, has definitely reduced the accident rate .

Furthermore, management that requires a job schedule from subordinates has a better safety level and a lower accident rate on its projects. Projects that always had a job schedule for their activities had achieved an average safety level and accident rate of 88 and 9 respectively. On the other hand, projects that never had a job schedule achieved a safety level and accident rate of 49 and 53 respectively; refer to Table 5.7.

These results prove the importance of the job schedule for any project, even though some people believe that the job schedule has a negative effect on safety due to the pressure it applies on workers to meet dead-lines. The results on Table 5.7 show the opposite. Projects that always have a job schedule for their activities have a higher safety level and a lower accident rate.

The relationship between the job schedule and the accident rate is attributed to the fact that those projects that plan and schedule the activities in advance, and try to meet the schedule as much as they can, minimize the causes that lead to serious accidents in the absence of the planning and scheduling.

Also, it was found that planning meetings have a great affect on safety, whether they are held between middle management and their subordinates or with outside parties who are directly or indirectly involved in the project.

Projects that always hold a planning meeting have an average safety level of 88 and average accident rate of 10, whereas projects that have never held a planning meeting have an average safety level of 53 and an average accident rate of 49; refer to Table 5.9

Undoubtedly, planning meetings prevent confusion on the project and organize activities and their locations. Furthermore, safety aspects are sometimes presented and discussed in these meetings, which in turn will help increase the safety level and lower the accident rate in a project.

Safety meetings were also found to be an important element in the reduction of the accident rate and they promote the safety level on a project significantly. It was found that projects that always held safety meetings had an average safety level of 91 and average accident rate of 5. On the other hand, projects that never had safety meetings had an average safety level of 53 and an average accident rate of 49; refer to Table 5.11.

This is attributed to the fact that workers are reminded periodically of unsafe acts and their consequences. Therefore, they are more cautious. Furthermore, foremen will also be reminded during these meetings of unsafe conditions and they will eliminate this type of conditions.

Another important factor that enhances the safety level and reduces the accident rate is safety accountability. Management who praise and reward workers and at the same time reprimand and penalize unsafe workers maintain a good safety record.

The results showed that projects that have safety accountability had an average safety level of 90 and average accident rate of 10. However, projects that never had safety accountability had an average safety level of 56 and an average accident rate of 43. (refer to Table 5.13).

If the Management is really concerned about safety, then this will be transmitted to the workers, who will also know that they will be held accountable for their unsafe actions.

Management personnel who recruit experienced workers and maintain the good long-hired employees of their work force achieved good safety records. Projects that had over 75% of their work force as long-hired employees had an average safety level of 78 and average accident rate of 21, whereas projects that had less than 70% long-hired workers had an average safety level of 60 and an average accident rate of 45; refer to Table 5.15.

This is due to the fact that workers who have worked for the same employer on other projects are very familiar, not only with the company policies, but also with other fellow workers. Over the years, they develop friendships with each other and recognize their personal problems, whether they are related to work or private ones.

This kind of bond between workers will not only have a positive effect on productivity. It also has a considerable impact on safety. Familiarity with fellow workers also adds unity to the job and satisfies the basic human need for friendship.

Meeting with and training new workers is often neglected by management, even though this item has a considerable effect on safety, as is proven by the survey. Projects that have management personnel that meet and coach new workers had an average safety level of 89 and an average accident rate of 11. While projects that do not train new workers, but just put them to work right away, have an average safety level of 79 and average accident rate of 28.

The results shows the importance of meeting new workers and guiding them on safety. Many new workers are not new to construction work but are new to the job site and the job personnel. The new environment can put more stress and frustration on the new worker and these are only relieved when he is made to feel at ease and is given the opportunity to become oriented to the job. There is no doubt that supervisors' involvement with new workers places the employees in a better state of mind and enhances their grasp of safe work requirements.

The following table shows the correlation magnitude between accident rate and items such as safety level , safety officer , etc.

Table 6.1: The Correlation (r) Values for Items that have an effect on the reduction of accident rate.

Item	Correlation (r)
Safety Level	-0.95
Safety Officer	-0.94
Job Schedule	-0.91
Planning Meetings	-0.84
Safety Meetings	-0.75
Training New Workers	-0.56
Workers' Experience	-0.24

In conclusion, it was found through this research that, as the safety level increases on a project, the accident rate decreases. Also, it was found through this research that, as the project size increases, the safety level increases too. This is attributed to the fact that big projects are executed by big and qualified companies which have an existing, established safety program, and employees within these projects / companies are held accountable when it comes to safety. Furthermore, it was found that the greatest contributor to accident rate reduction is the safety officer assigned to a project and the worker-experience factor has the least effect on accident level, as shown in the table above.

6.8 Ranking of Divisions

The divisions in the checklist are ranked according to the safety level score, and the ranking in large, medium and small projects is as follows:

Large projects

1.Scaffolding.

2.Protective Equipment & Site Safety Admin.

3.Welfare facilities.

4.Cranes and Lifting devices.

5.Heavy Equipment.

6.Concrete formwork.

7.Electrical.

8.Site layout & House keeping.

9.Hand tools & Power tools.

10.Excavation & Shoring

11.Transportation.

12.Fire Prevention.

13.Cartridge Oper. tools.

14.Air compressors.

15.Welding and cutting.

16.Compressed Gas.

17.Blasting.

18.Chemical.

Medium Projects

1.Scaffolding.

2.Hand tools & Power tools.

3.Site layout & House keeping.

4.Concrete formwork.

5.Cranes and Lifting devices.

6.Protective Equipment & Site Safety Admin.

7.Electrical.

8.Hand tools & Power tools.

9.Welfare facilities.

10.Transportation.

11.Excavation & Shoring.

12.Air compressors.

13.Fire Prevention.

14.Cartridge Oper. tools.

15.Welding and cutting.

16.Compressed Gas.

17.Blasting.

18.Chemical.

Small projects

1.Scaffolding.

2.Electrical.

3.Concrete formwork.

4.Site layout & House keeping.

5.Cranes and Lifting devices.

6.Hand tools & Power tools.

7.Excavation & Shoring.

8.Transportation.

9.Heavy Equipment.

10.Protective Equipment & Site Safety Admin.

11.Air compressors.

12.Compressed Gas.

13.Welding and cutting.

14.Welfare facilities.

15.Fire Prevention.

16.Cartridge Oper. tools.

17.Blasting.

18.Chemical.

The problem areas are in the chemical and blasting divisions, which are common in all the three types of projects. The chemical and flammable materials are not placed in shaded areas. There are no warning signs at the locations where they are stored. With respect to the blasting activity, workers are not wearing breathing apparatus while performing blasting and there are no warning signs to alert people who are in the vicinity.

6.9 RECOMMENDATIONS

As a result of the data presented in the data analysis chapter, it is recommended that the following items be implemented during the course of any project.

1. Chemical and flammable material should be stored in shaded areas that have warning signs on them.

2. Workers who are performing blasting should wear breathing apparatus.

3. Warning signs should be placed in areas where blasting activity is carried out.

4. A Safety Officer needs to be assigned to projects to make sure that all activities are being carried out safely.

5. A Job Schedule should be established which will identify critical activities and enhance the preparation for them.

6. Planning meetings should be conducted specifically prior to commencing the work in important and dangerous activities that involve different groups of crafts or outside parties.

7. Safety meetings should be conducted periodically. At them, safety talks and safety films should be presented to refresh and promote safety among workers.

8. Safe behavior and actions should be praised and unsafe actions should be reprimanded.

9. New workers should not be put to work immediately when they are hired. They should be given a reasonable time to get familiar with the environment. They should also be trained and watched by their foremen and co-workers.

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APPENDIX - I

CHAPTER-3 : INSPECTION CHECKLIST

NAME OF CONTRACTOR:	INSPECTION DATE:	TOTAL NO. OF EMPLOYEES ON SITE:	
CONTRACTOR'S REP.:	JOB. TITLE:	CONTRACTOR'S PHONE NO.:	PROJECT SIZE:
PROJECT NAME:	LOCATION:	OWNER NAME: PHONE NO:	

SAFETY ASSESSMENT			SAFETY ASSESSMENT		
3.1. SITE LAYOUT & HOUSE KEEPING *(Weight =)*	Value	Score	3.4 TRANSPORTATION *(Weight =)*	Value	Score
Site Access Roads	0-100				
Security Fences/Gates	0-100		Use of Seat Belts	0-100	
Site Access Signs	0-100		Licensed Operators	0-100	
Trash Containers/Lids	0-100		Overall Operating Condition	0-100	
Daily Clean-up	0-100		Tires/Lights/Brakes/Signals/etc.	0-100	
Material Stacking	0-100		Fire Extinguishers	0-100	
Aisle Ways	0-100			***Avg.***	
Old Timber Derailed	0-100		3.5. EXCAVATION & SHORING (Weight =)	Value	Score
Overall Condition	0-100		Shoring Trench/Box/Sloping	0-100	
Lights	0-100		Blower	0-100	
	Avg.		Spoil Clearance	0-100	
3.2 PROTECTIVE EQUIPMENT & SITE SAFETY ADMINISTRATION *(Weight =)*			Barriers/Warning Signs/Lights	0-100	
Helmets	0-100		Access/Egress (Ladders)	0-100	
Eye Protection	0-100		Cross Over	0-100	
Gloves	0-100		Void Space Procedures	0-100	
Safety Shoes	0-100		Air Tests	0-100	
Accident Reports	0-100		Rescue Equipment	0-100	
Construction Safety Manual on Site	0-100			***Avg.***	
First Aid Station/Kit	0-100		3.6 WELDING, CUTTING (Weight =)		
Emergency Telephone Number Posted	0-100		Proper Acetylene Pressure	0-100	
	Avg.		Acetylene On/Off Wrench	0-100	
3.3. FIRE PREVENTION *(Weight =)*	Value	Score	Gauges/Hoses Condition	0-100	
Adequate Fire Extinguishers	0-100		Operator's Protective Equipment	0-100	
Proper Type Extinguishers	0-100		Cable Cord-No Splice	0-100	
Fire Extinguisher Training	0-100		Elect'l. Holder/Ground Clamp Condition	0-100	
Tags/Inspected Fire Extinguishers	0-100		Ventilation	0-100	
Adequate Water Barrels/Buckets	0-100			***Avg.***	
Fire Hose Tested	0-100				
Emergency Telephone Numbers Posted	0-100				
Storage of Flammable/Combustibles	0-100				
Test Smoke Detectors	0-100				
	Avg.				

APPENDIX - I (CONT.)
INSPECTION CHECKLIST

NAME OF CONTRACTOR:	INSPECTION DATE:	TOTAL NO. OF EMPLOYEES ON SITE:	
CONTRACTOR'S REP.:	JOB. TITLE:	CONTRACTOR'S PHONE NO.:	PROJECT SIZE:
PROJECT NAME:	LOCATION:	OWNER NAME: PHONE NO:	

SAFETY ASSESSMENT			SAFETY ASSESSMENT		
3.7 COMPRESSED GAS (Weight =)			3.10 CARTRIDGE OPER. TOOLS		
Cylinder Secured	0-100		Proper Cartridge Strength	0-100	
Proper Storage (Shade/Separation)	0-100		Penetration to Safe Zone	0-100	
Protective Caps in Place	0-100		Low Velocity Tool	0-100	
Conditions of Cylinders/Connections	0-100		Proper Maintenance of Tool	0-100	
Proper Handling	0-100		Certified Operators	0-100	
Proper Color Coding	0-100			*Avg*	
	Avg.				
3.8 SCAFFOLDING *(Weight =)*			3.11 CONCRETE FORMWORK (Weight =)		
Base and Sole Plates	0-100		Timber Adequate Strength	0-100	
Condition of Frame Members	0-100		Supports Plumb & Level	0-100	
Plumb and Level	0-100		Protective Clothing & Equipment	0-100	
Proper Couplers	0-100		Firm Footings for Supports	0-100	
Ties/Outloggers	0-100		Side Slope Bracing	0-100	
Planking	0-100		Shoring Layout on Site	0-100	
Toe Board Guard Rails	0-100		Truck Spotter	0-100	
Proper Castors Condition/Locks	0-100		Work Platforms	0-100	
Scaffold Access	0-100			*Avg.*	
Proper Loading	0-100		3.12 CRANES & LIFTING DEVICES *(Weight =)*		
	Avg.		Current Inspection Sticker	0-100	
3.9. HAND TOOLS AND POWER TOOLS/. *(Weight =)*			Saudi Arab Licensed Operator	0-100	
Properly Guarded	0-100		Saudi Aramco Certification	0-100	
Tool Rest	0-100		Road Radius Indicator	0-100	
Overall Condition	0-100		Safety Latches (Hook)	0-100	
Correct Grinder Disc Speeds	0-100		Condition of Wire Ropes	0-100	
Cable/Hose Connections	0-100		Safe Load Charts (Arabic/English)	0-100	
Operator's Protective Equipment	0-100		Proper Use of Outrigger	0-100	
Damaged Hand tools	0-100		Signal man used	0-100	
	Avg			*Avg.*	

APPENDIX - I (CONT.)
INSPECTION CHECKLIST

NAME OF CONTRACTOR:	INSPECTION DATE:	TOTAL NO. OF EMPLOYEES ON SITE:

CONTRACTOR'S REP.:	JOB. TITLE:	CONTRACTOR'S PHONE NO.:	PROJECT SIZE:

PROJECT NAME:	LOCATION:	OWNER NAME: PHONE NO:

SAFETY ASSESSMENT			SAFETY ASSESSMENT		
3.13 AIR COMPRESSORS *(Weight =)*	Value	Score	3.16 WELFARE FACILITIES (Weight =)		
Pressure Relief Valves Operational	0-100		Medical Facilities/Suppliers	0-100	
Air Pressure Gauges	0-100		Designated Smoking Areas	0-100	
Hose and Connections	0-100		Washing Facilities	0-100	
Coupling Safety Wired	0-100		Drinking Water & Cups	0-100	
General Condition	0-100		Toilet Facilities/Sanitation	0-100	
Guards	0-100		Ventilation	0-100	
Drain	0-100		Eating Facilities	0-100	
	Avg.			***Avg.***	
3.14. ELECTRICAL *(Weight =)*	0-100		3.17 HEAVY EQUIPMENT (Weight =)	Value	Score
Correct Voltage	0-100		Roll-over Protection	0-100	
Ground Fault Interrupters Used	0-100		Back-up Alarms	0-100	
Circuit 3-Wire Ground	0-100		Overall Conditions	0-100	
Receptacles/Plugs	0-100		Licensed Operators	0-100	
Services Panel Fused	0-100			***Avg.***	
Overall Condition	0-100		3.18 CHEMICAL *(Weight =)*		
Warning Signs	0-100		Isolated Storage	0-100	
Hazardous Locations	0-100		Chemical Data Sheet on Site	0-100	
	Avg.		Warning Signs	0-100	
3.15 BLASTING *(Weight =)*			Scott Air Pack	0-100	
Operator's Hood (Air-Supplied)	0-100		Area Locked	0-100	
Air Filters (Cool Air to Hood)	0-100		Labels	0-100	
Dead Man Controls	0-100			***Avg.***	
Hoses Properly Grounded	0-100				
Operator's Operative Clothing	0-100				
Helper's Protective Clothing	0-100				
Remote Area/Warning Signs	0-100				
Condition of Air Purity	0-100				
	Avg				

APPENDIX - II

QUESTIONNAIRE

1- What is the riyal value of this project?______________Million

Less than 5 million ( ) 5 to 20 million ( ) Above 20 million ( )

2- When did this project start? ______________

3- What is the average number of men in the project? ________________

4- On average, how many hours do they work per week? ___________

5- Do you have a full-time safety officer assigned to the project?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

6- Is there a job schedule?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

7- If there is a job schedule, Who sets it up?

Project manager ( ) Project superintendent ( ) Home office ( )

8- Do you make use of the schedule?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

9- Do you have planning meetings?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

10- If you have planning meetings, who attends these meetings?

(You can select more than one answer for this question.)

Superintendents ( ) Foremen ( ) Workers ( )

11- Who do you report to ? (Title)______________________

12- How often do you communicate with your superior?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

APPENDIX - II (CONT.)

13-How often is he out on the job?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

14- Do you have tool box meetings (safety meetings) on this job?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

15- Have you ever sought advice from anyone regarding safety on your jobs?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

16- How many injuries have you had on this job?

Doctor's cases_______________

Lost-day cases _____________

17- Is there a safety incentive or safety bonus in the company or on this job?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

18- Are you evaluated at all in terms of your safety record?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

19- If a foreman sees another crew working unsafely, does he have the authority to stop the work?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

20- Have you ever had any portion of your job stopped because of safety?

Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

21- How many of your men have worked for you on other jobs?

Over 75% ( ) 50 to 75% ( ) 25 to 50% ( )

10 to 25% ( ) 0 to 10% ( )

22- Do you ever get involved with new workers?
Always ( ) Frequently ( ) Sometimes ( ) Rarely ( ) Never ( )

APPENDIX - III

CALCULATIONS

PROJECT # 1

Accident Rate	$= \dfrac{\text{Number of recordable injuries and illness} \times 200{,}000}{\text{Number of employee exposure hours}}$
Average number of employees on site	= 30
Each employee exposure hours	= Number of Weeks x Number of Working Hours/Week.
	= 78 x 40 = 3120 hrs.
Time period for all employees	= 30 x 3120 = 93600 hrs.
Recordable injuries	= 20
Accident rate	$= \dfrac{20 \times 200{,}000}{93600}$
	= 20 x 2.14
	= 42.8

APPENDIX - III (CONT.)

CALCULATIONS

Determining the weight for each items:

Item #1

$$\text{Weight} = \frac{3+4+4+5+10}{5} = 5.2$$

Item #2

$$\text{Weight} = \frac{2+6+10+4+10}{5} = 6.4$$

Item #3

$$\text{Weight} = \frac{8+10+10+8+7.5}{5} = 8.7$$

Item #4

$$\text{Weight} = \frac{2+4+4+4+2.5}{5} = 3.3$$

Item #5

$$\text{Weight} = \frac{3+4+4+5+2.5}{5} = 3.7$$

Item #6

$$\text{Weight} = \frac{4+6+5+7+7.5}{5} = 5.9$$

Item #7

$$\text{Weight} = \frac{4+8+10+7+7.5}{5} = 7.3$$

APPENDIX - III (CONT.)

CALCULATIONS

Item #8

$$\text{Weight} = \frac{12+10+7+7+7.5}{5} = 8.7$$

Item #9

$$\text{Weight} = \frac{2+3+6+5+2.5}{5} = 3.7$$

Item #10

$$\text{Weight} = \frac{4+6+5+5+5}{5} = 5$$

Item #11

$$\text{Weight} = \frac{3+4+4+4+2.5}{5} = 3.5$$

Item #12

$$\text{Weight} = \frac{6+4+3+6+2.5}{5} = 4.3$$

Item #13

$$\text{Weight} = \frac{5+3+4+5+2.5}{5} = 3.9$$

Item #14

$$\text{Weight} = \frac{12+3+2+3+2.5}{5} = 4.5$$

Item #15

$$\text{Weight} = \frac{5+4+2+7+10}{5} = 5.6$$

APPENDIX - III (CONT.)

CALCULATIONS

Item #16

$$\text{Weight} = \frac{8+6+6+6+7.5}{5} = 6.7$$

Item #17

$$\text{Weight} = \frac{12+12+10+7+7.5}{5} = 9.7$$

Item #18

$$\text{Weight} = \frac{5+3+4+5+2.5}{5} = 3.9$$

$$\text{Total} = 52.9 + 47.1 = 100$$

CALCULATING THE AVERAGE IN THE CHECK LIST

PROJECT #1

Item #1:

Average = 0.0

Item #2:

$$\text{Average} = \left(\frac{100+100+100+50+80+60+0+0+70+0}{10}\right) \times 6.4\%$$

$$= 56 \times 6.4\% = 3.58\ \%$$

Item #3

Average = 0.0

Item #4

Average = 0.0

Item #5

$$\text{Average} = \left(\frac{100+80+70+60+100}{5}\right) \times 3.7\%$$

$$= 82 \times 3.7\% = 3.03\%$$

Item #6

Average = 0

APPENDIX - III (CONT.)

PROJECT #1

Item #7

Average $= \left(\frac{60+0+80+30+20+0+0+0+0}{9}\right) \times 7.3\%$

$= 21.11 \times 7.3\% = 1.54\%$

Item #8

Average $= \left(\frac{0+70+50+100}{4}\right) \times 8.7\%$

$= 55 \times 8.7\% = 4.79\%$

Item #9

Average $= 0.0$

Item #10

Average $= \left(\frac{0+30+40+20+70+0+0+80}{8}\right) \times 5\%$

$= 30 \times 5\% = 1.5\%$

Item #11

Average $= 0.0$

Item #12

Average $= \left(\frac{30+0+40+50+0+0+0+0}{8}\right) \times 4.3\%$

$= 15 \times 4.3\% = 0.65\%$

PROJECT #1

Item #13

Average = 0.0

Item #14

$$\text{Average} = \left(\frac{50+100+80+90+0}{5}\right) \times 4.5\%$$

$$= 64 \times 4.5\% = 2.88\%$$

Item #15

$$\text{Average} = \left(\frac{80+20+0+0+0+0+100+0+0}{9}\right) \times 5.6\%$$

$$= 22.22 \times 5.6\% = 1.24\%$$

Item #16

$$\text{Average} = \left(\frac{100+100+0+0+70+0+0}{7}\right) \times 6.7\%$$

$$= 38.57 \times 6.7\% = 2.58\%$$

Item #17

Average = 0.0

Item #18

Average = 0.0

$$\text{Total} = 0+3.58+3.03+1.54+4.79+1.5+0.74+2.88+1.24+2.58$$

$$= \frac{21.88\ \%}{(100-5.2-8.7-3.3-5.9-3.7-3.5-3.9-9.7-3.9)}$$

$$= 41.92\ \%$$